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INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION

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ANNUAL REPORT
Intermountain Forest and Range Experiment Station

As in previous years, our annual report gives a brief review of the significant research work of each division for the past year. The Station's research program is organized on a divisional basis because that is the most convenient way to apply specialized thinking and talent to the solution of specific wild-land management problems. We recognize, however, that the management of wild lands is an activity calling for the closest integration of the many skills applied to bring about the preservation of the productive capacity and the wise use of our wild-land resources. Consequently, there is conscious effort to integrate the research work conducted under our divisions of Range Management, Range Reseeding, Forest Management, Range Economics, and Watershed Management both at the field and station levels.

Cooperation between our Station and the action agencies, such as National Forest Administration and the Bureau of Land Management, with private range land operators and water users makes for a better programming of our research. Active cooperation with other research institutions and organizations enables us to do more research with available finances and allows for coordination and integration of investigations over a broad front. We are actively cooperating in phases of wild-land research with the Bureau of Land Management, Bureau of Plant Industry, Soils and Agricultural Engineering, Fish and Wildlife Service, Soil Conservation Service, Utah State Agricultural College, Utah State Fish and Game Commission, Nevada Agricultural Experiment Station, and the University of Idaho.

RANGE MANAGEMENT RESEARCH

In the last annual report a brief problem analysis for range management research was outlined. In this, three problem areas of particular importance were singled out: Mountain grasslands, granitic soils of southwestern Idaho, and the Colorado River basin.

Progress has been made on phases of all these broad problems. Because of the urgency for information relating to sedimentation in the Colorado River, Ellison made four exploratory trips, each of about a week's duration, into various parts of the river basin. Conditions in a wide variety of types were inspected, and available facilities for ecological field studies were appraised. It has been concluded that the most effective ecological research for a beginning on this problem would be extensive observations on vegetal composition in relation to past grazing management, and on plant growth and utilization in relation to current grazing practices. Because of the great diversity and extent of the sediment-producing lands, such work should touch many parts of a wide area. Considerable effort is warranted in bringing to light areas that have not been greatly modified by grazing. These are needed as standards for judgment of range condition, particularly in distinguishing between accelerated (man-induced) and normal (geologic) erosion. Observations of livestock exclosures in northern

Nevada, southern Idaho, and in the Colorado River basin itself, show that more sustained effort in maintenance will be required than was formerly considered necessary if these exclosures are to yield much information about the influence of grazing on desert vegetation.

The manuscript, "Subalpine Vegetation of the Wasatch Plateau, Utah," covering fundamental ecological studies, is still in process of revision. Work on this has been delayed partly because of the effort required in the Colorado River basin. A Station Research Paper on indicators of range condition in the aspen type will be prepared during the winter of 1950-51. Analysis of the Nevada enclosures has been carried through to the progress report stage, but the nature of a suitable published report has not yet been determined.

The manuscript, "Indicators of Condition and Trend on High Range Watersheds of the Intermountain Region," which was in Washington at the time of the last annual report, has been revised and resubmitted to Washington. This is intended for the Agriculture Handbook series. "Ecological Trends After Controlled Burning of Sagebrush-Grass Range on the Upper Snake River Plains," a manuscript intended as a Technical Bulletin, has been submitted to the board of review. "Management of Winter Sheep Ranges of the Intermountain Region," intended as a Circular, is undergoing further revision. The problem analysis for the big-game livestock project has been completed and issued as Research Paper No. 24.

In general, field work has been held to a maintenance level in order to expedite preparation of manuscripts. However, the reinventory of the gopher plots at the head of Ephraim Canyon was made, the salient results of which are given later in this report. Field work on food habits of deer, sheep, and cattle has been completed. Plots have been planted to test the productivity of range in openings as compared with that under aspen canopy, a question pertinent to accurate judgment of range condition. Field assistance has been given K. W. Parker in his study of methods of evaluating range condition and trend, and assistance has been given the Region in a field training meeting and in other ways. These activities were planned for in last year's annual report.

It has not been possible to launch a research attack on the problems of cheatgrass, blackbrush, or halogeton. The reexamination of old plots and quadrats on the Boise, which we had hoped to make during each of the past two years, has not been possible as yet. A problem of developing standards of proper range utilization on the Uinta, which the Region considers very urgent, may cause further postponement of the Boise work.

SUMMER RANGE

Effects of pocket gophers on subalpine grassland

Evidence of pocket gophers (Thomomys) is often conspicuous on herbaceous subalpine range, making range users wonder what influence pocket gophers have on vegetation. Some believe that pocket gophers reduce total productivity by foraging and by covering vegetation with their mounds, or that they change the composition of vegetation adversely. Others suggest that they may play an important role in mixing and aerating the soil so that the net effect is an increase in vegetation or improved composition.

An experiment was set up cooperatively with the Fish and Wildlife Service in 1942 to measure the influence of pocket gophers on subalpine range. At this time a study area of 4 acres at the head of Ephraim Canyon in central Utah was fenced against grazing by livestock. Since 1942 one-half the area has been trapped consistently while the gophers in the other half have been undisturbed. Although gophers have also been removed from a wide border around three sides of the trapped area, a few have managed to invade, chiefly by burrowing under the snow in winter. These are cleaned out each summer, and the relatively few gopher diggings on the surface show that the trapping is highly effective. Since the difference in number of gophers is clearly very great, it is felt that "gophers absent" as a characterization of the trapped area is sufficiently accurate to contrast with "gophers present" for the other half.

The study site, which was selected to be as homogeneous as possible, is a moderate westerly slope, at about 10,100 feet elevation. No trees and practically no shrubs occur on it. As a result of years of heavy grazing by domestic livestock, particularly sheep, this range is now dominated by rhizomatous species--chiefly Artemisia discolor, Penstemon rydbergii, and Achillea lanulosa--and by such aggressive seeders as Stipa lettermani and Taraxacum officinale.

The vegetation has been sampled by weight estimates on permanent 1 x 3 m. plots. Considerable care has been taken in training to insure reasonable accuracy of estimates. In addition, estimators have made a practice of alternating between plots under the two treatments so that any tendency for a drift in standards would not influence the comparison. Herbage samples have been collected and dried so that the estimates could be reduced to an air-dry basis. The study extends over 8 years, estimates having been made in the year of establishment, 1942, and again in 1944 and 1950.

The most outstanding result of this study, up to now, is that changes in vegetation have been slight. To the eye there is very little difference between the two areas, and although some observers have felt they could detect a difference, they have seldom been sure about it. As shown by the totals in table 1, production on the two areas has not changed materially over the years. The decline where gophers have been removed is somewhat more marked than where they

Table 1. Air-dry herbage production in 1942, 1944, and 1950, where pocket gophers were practically eliminated and where they were present

	Gophers absent			Gophers present		
	1942	1944	1950	1942	1944	1950
				Pounds per acre		
Taprooted species						
Agoseris pumila	8.63	11.97	14.09	10.41	17.49	22.62
Taraxacum officinale	65.03	97.88	94.39	289.30	241.13	24.45
Others	4.51	8.35	19.90	4.43	5.42	2.78
Subtotal	78.17	118.20	128.38	304.14	264.04	49.85
Rhizomatous species						
Achillea lanulosa	76.63	110.11	83.65	130.77	140.67	76.65
Artemisia discolor	335.55	204.14	166.94	167.25	150.18	309.99
Penstemon rydbergii	148.97	154.50	135.07	299.68	266.73	353.64
Others	21.74	36.23	54.70	20.89	43.24	102.14
Subtotal	582.89	504.98	440.36	618.59	600.82	842.42
Grasses						
Agropyron trachycaulum	13.97	34.78	10.89	26.09	39.56	51.61
Stipa columbiana	6.76	11.78	6.15	6.02	13.64	21.01
Stipa lettermani	229.50	241.06	231.83	69.13	58.89	52.95
Others	3.29	4.99	1.82	9.71	11.84	16.41
Subtotal	253.52	292.61	250.69	110.95	123.93	141.98
Tall herbs	27.66	37.14	40.00	35.88	40.46	47.25
Ephemerals	48.89	33.08	22.72	25.09	24.12	13.31
Annuals	9.17	6.20	0.00	23.00	19.47	8.05
Shrubs	0.28	2.26	0.96	-	-	-
Total	1,000.58	994.47	883.11	1,117.65	1,072.84	1,102.86

have been undisturbed, so that it cannot be said that pocket gophers have reduced total production. On the other hand, there is no indication that they have increased it.

Perhaps the reason that differences are not more apparent to the eye is that the vegetation itself is naturally variable. Table 1 illustrates this point. In 1942 before the treatment was imposed, Stipa lettermani was over three times as abundant on the area where gophers were to be removed as on the area where they were to be undisturbed. Common dandelion (Taraxacum) was more than four times as abundant on one side as on the other.

One change that is probably due to gophers is the strong decline in dandelion where gophers have been present. Here in 1950 there was less than 10 percent of the dandelion that was present in 1942. Dandelion on the area where gophers have been trapped increased about 50 percent during the first 2 years of trapping and maintained itself at about the same level for the last 6 years. Dandelion is believed to be one of the favorite food plants of pocket gophers: numerous caches have been found in which the dried taproots of this species were the principal item stored, and new runways are sometimes marked on the surface by the withered tops of dandelions from which the roots have been severed. It appears, therefore, that foraging by pocket gophers has reduced the dandelion.

The fact that dandelion has declined so markedly on the "gophers present" area raises another question: Why were dandelions so much more abundant on this area in 1942 when gophers were also undisturbed? If the answer lies in the relative numbers of gophers and dandelions per acre, it seems probable that the population of pocket gophers has increased as compared with the population that was there before the land was fenced. This would accord with many observations that pocket gophers tend to concentrate in livestock exclosures.

It is interesting to note that the native Agoseris, which is very much like the introduced dandelion in growth form, and which presumably would be a good pocket-gopher food, has behaved differently. Agoseris has increased on both areas, and has even increased more where pocket gophers were present than where they were absent. Despite appearances, therefore, it may not be much eaten by pocket gophers. Other taprooted species--particularly Lesquerella, Arabis, and Thlaspi--have increased rather markedly where gophers have been absent, but less markedly where they have been present.

Among rhizomatous species, which make up more than half the total vegetation, and with the exception of yarrow (Achillea), there is a tendency for rather marked increases where pocket gophers have remained undisturbed. The change in sweetsage (Artemisia) is particularly notable. Over the 8-year period this herbaceous sage declined strongly where gophers were removed and increased strongly where they remained. This change in sweetsage has been the major influence affecting the subtotals for the rhizomatous species, and it is more than enough to account for the 117-pound decline in total production between 1942 and

1950 where pocket gophers have been removed. A possible explanation is that sweetsage production may be augmented where it has the opportunity to invade small bare areas formed by gopher diggings, and that, on the other hand, production declines when few or no bare areas are present and sweetsage must compete on equal terms with the other species with which it is intermingled.

Grasses have changed relatively little where pocket gophers have been removed, but they have increased markedly--particularly *Agropyron* and *Stipa columbiana*--where pocket gophers have been undisturbed. It would appear from this that pocket gophers are not harmful to native grasses.

Tall herbs have increased slightly on both areas. These include, in order of abundance, *Thalictrum fendleri*, *Potentilla pulcherrima*, *Geranium richardsonii*, *Ligusticum porteri*, and *Polemonium foliosissimum*. Such an increase in tall herbs is generally noted on subalpine range after sheep have been excluded for several years. There is no difference that is clear-cut enough to be ascribed to pocket gophers.

Ephemerals and annuals--chiefly *Viola nuttallii*, *Ranunculus inamoenus*, *Delphinium menziesii*, *Collomia linearis*, and *Polygonum douglasii*--have declined strongly on both areas. Annuals have declined more slowly where gophers have remained undisturbed, and at times they have been conspicuous on the bare soil of old gopher mounds. Annuals may therefore be encouraged by gophers. However, the great decline of ephemerals and annuals, like the increase of tall herbs, probably relates more to elimination of livestock grazing than to influence of pocket gophers.

The conclusions from this study bear out observations reported from a somewhat similar study on the Grand Mesa in Colorado (Rocky Mountain Forest and Range Experiment Station, 1947 Annual Report, pp. 51-54), where changes in subalpine vegetation over a 6-year period were slight. If pocket gophers do have a pronounced effect on this kind of vegetation, the Utah study shows that more than 8 years are required for that effect to become manifest.

BIG GAME-LIVESTOCK RANGE

Deer Food Habits.--It is the generally accepted belief that deer are essentially browse eaters, and when one considers the yearly diet this is probably true. That it may not be true with respect to the summer deer diet is indicated by recent observations in three vegetal types in central Utah.

The results of the study are presented in figure 1. It is evident from these graphs that forbs made up about two-thirds of the early deer diet and gradually declined in importance as the summer progressed. On the other hand, browse made up only about one-fourth of the early diet; but increased in importance until, by late summer, it accounted for nearly 85 percent of the diet in the spruce-fir and browse types, and exceeded forbs by a small margin in the aspen type. The small difference between the positions of forbs and browse in the aspen type may be explained by the fact that forbs remain succulent longer there than in the other types. Grasses maintained a low but fairly constant place in the diet throughout the summer. The similarity of the relationships between the three forage classes in each type would indicate that type has little, if any, effect on summer forage preference of deer.

In every type the deer had a "normal" selection of each forage class, that is, they were not forced to consume any particular forage because they had no choice. Browse made up the bulk of the vegetal composition in each type.

It is significant that forbs are far more important than browse in the diet during the period of time that they remain succulent.

Winter Deer Mortality and Range Condition.--The need for conservative stocking of deer was clearly shown during the severe winter of 1948-49. Winter deer mortality was compared on three areas in west central Utah: (1) South Oak Creek, in fair condition and conservatively stocked, (2) Meadow Creek, badly overgrazed and heavily overstocked, and (3) Heaston, severely depleted and heavily overstocked. The relations of forage supply to winter mortality were as follows:

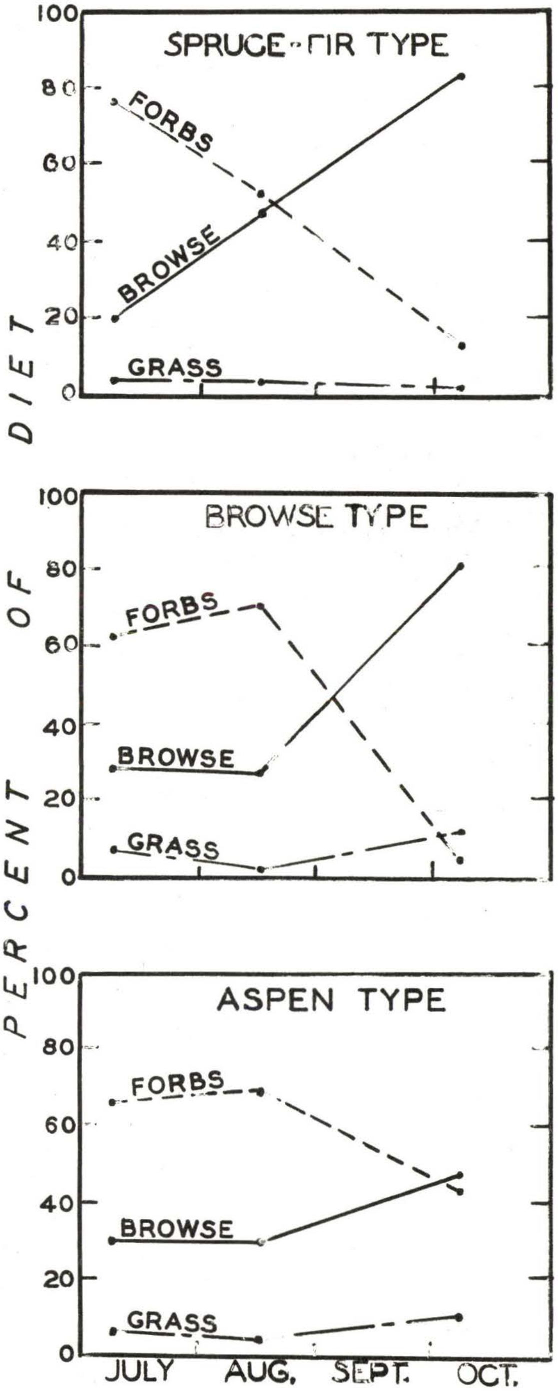

Fig. 1. Composition of summer deer diet, by classes of vegetation in three vegetal types, Utah, 1947-50.

Area	Rate of stocking (Deer days per acre)	Available browse (Lbs./deer day, green wt.)				Winter mortality (Pct.)
		Good	Fair	Poor	Total	
South Oak Creek	22	4.9	9.1	43.3	57.3	9.5
Meadow Creek	54	0.8	6.1	5.6	12.5	25.8
Heaston	23	0.0	7.8	1.6	9.4	41.6

South Oak Creek and Heaston ranges have about the same rate of stocking per acre, yet Heaston, with only one-sixth as much forage per deer day and no good quality forage, had over four times the winter mortality of south Oak Creek. Meadow Creek, although badly overgrazed, is not so depleted as Heaston, and losses were less severe.

Winter losses of 50 percent or more were estimated in 1948-49 in some northern Utah deer herds where winter range was very limited. Popularly most of this loss was credited to severe winter weather. But at Oak Creek the winter was equally severe--one of the worst on record--yet winter deer losses were only a little above average. Thus the answer to heavy winter deer mortality in most cases is clear: balance deer numbers with available forage.

WINTER RANGE

Response of Black Sagebrush, Shadscale, and Rabbitbrush to Protection and Moderate Grazing

Responses of shrubs to protection and moderate grazing

Black sagebrush (*Artemisia nova*) is one of the most palatable forage plants on the winter sheep ranges of the Intermountain region. Most of the original black sagebrush ranges have been seriously depleted by excessive grazing and invaded by species of low palatability such as rabbitbrush and shadscale.

In 1937, three enclosures were established on black sagebrush ranges: one in Newark Valley west of Ely, Nevada, one in Spring Valley, east of Ely, and one in Snake Valley, north of the Desert Experimental Range in western Utah. Data on plant density were taken on these enclosures at various intervals during the 10-year period 1937-47. In addition observations were made on the behavior of black sagebrush and rabbitbrush at one edge of the Desert Experimental Range beginning in 1934.

In the Snake Valley enclosure in Utah density of black sagebrush increased more than 10 times between 1937 and 1947 (table 2). On the adjacent grazed range it increased only slightly.

Shadscale, a species of low palatability, was 1.8 times the density in the enclosure and 2.8 times the density on the grazed range in 1947 that it had been in 1937. The generally high densities in 1947 at the Snake Valley enclosure were undoubtedly due to unusually good rainfall the previous year, which was 60 percent above average.

Table 2. Density of black sagebrush and shadscale on an enclosure and adjacent grazed range at Snake Valley, Utah, 1937-1939-1947

Year	Black sagebrush		Shadscale	
	Enclosure	Grazed	Enclosure	Grazed
	Percent			
1937	.176	.235	1.619	1.669
1939	.345	.220	1.390	2.110
1947	2.134	.324	2.850	4.729

In the two Nevada enclosures density of black sagebrush increased in 1942 but showed a somewhat lower density in 1946 than was originally recorded in 1937 (table 3). On the adjacent grazed areas density of black sagebrush declined throughout the entire period, being half or less in 1946 of the amount originally recorded in 1937. Density of rabbitbrush also decreased slightly in the two enclosures, but gained on the grazed range, particularly at Spring Valley where in 1946 it was almost 3½ times as great as in 1937. Thus, while densities showed little change within the enclosures from 1937 to 1946, on the grazed range the palatable black sagebrush declined and at one area the much less palatable rabbitbrush increased strongly.

Table 3. Density of black sagebrush and rabbitbrush on two enclosures and two adjacent grazed areas in Nevada 1937-1947-1946

	Year	Black sagebrush		Rabbitbrush	
		Enclosure	Grazed	Enclosure	Grazed
		Percent			
Spring Valley	1937	3.735	2.010	.880	.690
	1942	4.815	1.375	1.780	1.275
	1946	3.598	1.115	.875	2.374
Newark Valley	1937	3.575	3.770	1.830	1.640
	1942	4.890	3.315	1.685	1.575
	1946	2.986	1.392	1.594	1.821

Improvement of black sagebrush range was obtained at the Desert Experimental Range under moderate grazing. In 1934 part of a heavily grazed black sagebrush range was fenced and placed under managed, moderate grazing. The other portion was continued under heavy grazing. By 1947 under moderate grazing black sagebrush density had increased 14 times (table 4). On the area which was heavily grazed, black sagebrush showed relatively little change. Under moderate grazing rabbitbrush decreased by more than half while under heavy grazing it increased more than 3½ times. This demonstration that improvement in black sagebrush range can be obtained under moderate grazing is important because it shows that black sagebrush ranges in fair to poor condition can be rehabilitated, without removing all livestock from the range.

Table 4. Density of black sagebrush and rabbitbrush on a heavily grazed range part of which was moderately grazed following 1934, and part continued under heavy use, Desert Experimental Range

Year	Black sagebrush			Rabbitbrush	
	Moderate	Heavy		Moderate	Heavy
			Percent		
1934	.243	.243		.861	.861
1938	.515	.165		1.300	2.100
1947	3.445	.325		.365	3.155

Herbage production on the winter range in relation to precipitation

Studies at the Desert Experimental Range, 50 miles west of Milford, Utah show a close, essentially linear, relation between herbage production as measured in October and precipitation received during the preceding 12-month period (October 1 to September 30).

Herbage production on 18 range pastures averaged 222 pounds per acre, air-dry weight, for the period 1938-47 and precipitation averaged 6.87 inches (table 5). The lowest yield during this period, 75 pounds per acre, occurred in 1943 when precipitation for the preceding 12 months was only 4.38 inches. The highest yield, 468 pounds per acre, occurred in 1947, when precipitation was 11.10 inches.

Table 5. Precipitation at the Desert Experimental Range for the period October 1 to September 30 and herbage yield recorded in October, 1938-47

Year	Precipitation	Yield	Year	Precipitation	Yield
	Inches	Lb/acre		Inches	Lb/acre
1938	8.82	264	1944	6.19	238
1939	6.66	209	1945	8.55	271
1940	4.62	104	*1946		
1941	7.72	241	1947	11.10	468
1942	3.78	128	Average	6.87	222.0
1943	4.38	75			

* Herbage yield not determined in 1946.

The correlation coefficient for precipitation and herbage production is .944. The equation for estimating yield for precipitation is

$$Y = 45.92x - 93.40 \pm 41.39$$

where x equals the total precipitation October 1 to September 30 and Y the computed herbage yield for October.

The close relation between precipitation and herbage production makes it possible to provide livestock operators with a reliable estimate of the forage production on the winter ranges by the first of October prior to the grazing season. For example, estimated herbage for last October based on precipitation was very low. Precipitation at the Desert Experimental Range headquarters was only 2.81 inches, 41 percent of average. Herbage yield computed for this much precipitation was 35.6 pounds per acre, only 16 percent of the 1938-47 average.

Actual yield may be expected to depart from the yield predicted by the equation. In some years computed yield exceeds actual yield, and in others it falls below. However, it is just as likely to be too high as too low. In two out of three years the error of estimate would not be likely to exceed 41 pounds above or below the actual yield.

Unfortunately prediction of herbage yield from precipitation on a widespread, practical scale is handicapped by two factors: great variation in precipitation from place to place on the winter range, and lack of a network of rain gages to give a good estimate of the precipitation for particular areas. To illustrate the variation that occurs from place to place, the precipitation catch obtained in Sykes rain gages placed at nine locations on the Desert Experimental Range for the period April 10 to November 15, 1950, varied from 0.84 inch to 3.22 inches (table 6). Although the elevation of the nine locations varied from 5,250 feet at headquarters to 7,110 feet, there appears to be no correlation between rainfall and altitude. Part of the variation is no doubt due to the location of gages with respect to ridges and mountains. Variation in the amount received in individual storms also varied widely.

Table 6. Precipitation from April 10 to November 15, 1950 at nine locations on the Desert Experimental Range

Elevation	Precipitation	Elevation	Precipitation
Feet	Inches	Feet	Inches
7,110	1.80	5,795	2.49
6,170	.90	5,495	1.23
6,150	2.07	5,350	1.34
6,015	3.22	5,250	1.57
5,890	.84	Average	1.72

Because precipitation appears to be the most important factor in determining forage production at any location in any one year, information as to the variation and type of rainfall pattern aids in appraisal of herbage production. Spotty and irregular rainfall results in wide variations in herbage production with one portion of the range producing almost normal amounts of herbage and another portion producing very little.

Few weather stations at present are located on the winter range, and therefore predictions of herbage yield cannot always be made with accuracy. A network of permanent rain gages would permit fairly reliable forage estimates to be made each fall.

SPRING-FALL RANGE

Rotation and rotation-deferred grazing by sheep

Continuous grazing during the spring growing season has long been recognized as one of the major causes of range deterioration. In order to prevent deterioration various methods of rotation and deferred grazing have been both proposed and followed. A simple rotation plan permits an area to be grazed fairly intensively for a short period at a different part of the grazing season each successive year. Thus, with four pastures on a 4-year rotation, each pasture would be grazed for only one-fourth of the season and at a different part of the season each year. A rotation-deferred plan also shifts the seasonal use of pastures, and in addition requires complete deferment of each pasture during one year of rotation.

A study of rotation and rotation-deferred grazing by sheep on spring-fall range was started at the Upper Snake River Research Center in 1941. This study consisted of three intensities of use under a simple rotation plan, and a single intensity under a rotation-deferred plan. Since fall use has comparatively little effect upon herbaceous species, the rotation systems were only in force during the spring. The pastures were all grazed at the same time in the fall, at spring intensities. The spring stocking rate for each of the four systems was as follows:

Light rotation--------14 sheep-days per acre
Moderate rotation----18 sheep-days per acre
Heavy rotation--------22 sheep-days per acre
Rotation-deferred----18 sheep-days per acre

Each system consisted of four pastures, and a complete rotation was accomplished in 4 years. The sheep were only in each pasture for a period of 10 to 18 days during the 40- to 45-day spring grazing season.

This study has now been through two complete rotations and is well into the third. The effects of the treatments on the vegetation have not yet been evaluated. However, weights of ewes and lambs grazed under these four systems demonstrate the effect of the three stocking intensities as well as differences between a simple rotation and a rotation-deferred plan. Although actual weight variations are not great, the trends (table 7) are important.

Pastures in the lightly stocked rotation consistently produced heavier ewes and lambs than in either the moderate, heavy, or rotation-deferred systems. Similarly, moderate stocking generally resulted in heavier sheep weights than heavy stocking.

Table 7. Effect of four systems of grazing on sheep weights[1]

Treatment	Sheep-days per acre	Average body weights[2] 1947 Ewes	1947 Lambs	1948 Ewes	1948 Lambs	1950 Ewes	1950 Lambs
		Pounds					
Light rotation	14	131.12	51.03	133.95	43.89	134.55	44.58
Moderate rotation	18	128.60	47.67	129.45	43.46	133.27	43.40
Heavy rotation	22	120.94	46.68	129.52	42.70	130.85	40.66
Rotation-deferred	18	129.67	46.67	128.54	41.81	132.18	41.89

[1] Adjusted to original weights by covariance analyses.
[2] Pastures were not grazed in 1949.

Sheep weights indicate, however, that a rotation-deferred plan is inferior to a simple rotation. Although the moderately stocked rotation and the rotation-deferred system both received a 4-year average spring use of 18 sheep-days per acre, actual use of the rotation-deferred system for 3 of the 4 years amounted to 24 sheep-days per acre. (Each year the three grazed pastures absorbed the sheep-days use from the one deferred pasture.) Consequently, the actual stocking rate, with respect to competition for forage between sheep, was even a little greater than that of the heavily stocked rotation. This was reflected by similarity of sheep weights between the rotation-deferred and heavy systems. Possibly the study has not been active long enough to cause sufficient vegetal changes to be reflected in the sheep weights.

Although one might expect, superficially, that light stocking would produce greater gains than heavy stocking, this is not easy to explain, since both the light and moderate rotations were in fairly good condition. In fact, pastures in all the systems produced ample forage (table 8), and were at no time completely utilized. This suggests that both ewe and lamb weights are fairly sensitive to the abundance of especially desirable feed, and that competition between sheep for the more desirable species, despite availability of other forage, may be more of a factor in governing sheep weights than is ordinarily recognized. The similarity in weight of sheep in the rotation-deferred and heavy rotation systems adds support to this suggestion. Probably this possibility should be taken into consideration when any grazing plan involves a high intensity of stocking for a short period of time.

Table 8. Herbage production in 1949 in pastures subjected to four systems of grazing

Treatment	Sheep-days per acre	Dry weight of herbage Grass	Forbs	Shrubs
			Pounds per acre	
Light rotation	14	141	89	349
Moderate rotation	18	120	115	466
Heavy rotation	22	114	73	482
Rotation-deferred	18	151	73	449

PROGRAM FOR 1951

Summer Range

1. Complete revision of manuscript covering fundamental ecological studies, "Subalpine Vegetation of Wasatch Plateau, Utah."

2. Prepare vegetal phase of joint report with Fish and Wildlife Service on pocket-gopher study at head of Ephraim Canyon.

3. Assist Region in training meeting and development of standards of utilization.

Big Game-Livestock Range Relationships

1. Summarize and report on deer food-habit study.

2. Summarize and report on deer-sheep food-habit study.

3. Continue studies on condition and trend on big game range, giving particular emphasis to mountain brush type where Administration is greatly in need of such information, both for livestock and big game.

4. Continue studies on proper use of game forage species.

Winter Range

1. Complete preparation of manuscripts, "Management of Winter Sheep Ranges in the Intermountain Region," and "Deer Utilization of Oakbrush Range."

2. Prepare report on vegetation inside and outside Nevada exclosures.

3. Continue grazing treatments of pastures at a maintenance level.

Spring-Fall Range

1. Complete preparation of manuscripts, "Effects of Controlled Burning of Sagebrush-Grass Range on the Upper Snake River Plains" and "Effects of Spring and Fall Grazing by Sheep on Vegetation of the Upper Snake River Plains."

2. Analyze data from two 4-year rotations of pasture study and from chemical analyses of forage plants (jointly with University of Idaho), and prepare reports.

3. Continue routine grazing treatments of pastures, collecting utilization data and minimum plot records.

Utilization Standards

1. Prepare Station Research Paper on indicators for judging condition and trend in aspen type.

2. Continue studies of aspen range condition.

3. Continue experiment to test productivity of range in openings as compared with that under aspen canopy as a basis for more accurate judgment of condition and trend.

RESEARCH IN RANGE RESEEDING

During 1950 reseeding research activities have followed the plan of work as set forth in the 1949 annual report. In addition to the continuation of studies previously begun, special emphasis was given to problems in the Colorado River basin, where considerable preliminary work has been started. New studies have also been begun on problems of recent occurrence within the region, of which perhaps the most notable example is the spread of halogeton.

COLORADO RIVER BASIN STUDIES

Realization of the need for technical information about revegetation in the Colorado River drainage basin has grown greatly in the last few years. The Station annual report for 1949 presented in general terms a statement of the acute sedimentation problem and a rough preliminary appraisal of the knowledge at our disposal that would contribute towards its solution. Immediate needs to help in planning were also stated in general terms. It was shown that we had a few studies in the Colorado Basin and a rather substantial list of studies and some complete data for areas just outside the basin. Much of this information covers some vegetal types that occupy sizable areas in the Colorado Basin.

On January 31 and February 1 a Southwest Federal Inter-Agency conference was held in Salt Lake City on the problems and needs of the Colorado River basin in which our reseeding staff participated. During the last of May and the early part of June two field trips were made--one on the west and the other on the east side of the Colorado River in Utah by representatives from the Intermountain Station and the Bureau of Land Management. The purpose of these trips was to examine plant cover and sedimentation conditions on some of the vegetal subtypes in the basin. A few sites were also tentatively selected as possible areas on which to conduct preliminary studies of methods and species suitable for improving the plant cover. With Chapline and members of the Range Management and Flood Control divisions, another trip was made in early July to inspect study sites now established and to examine conditions on the tentatively selected subtypes.

During November a preliminary series of studies with 40 species of grasses, shrubs, and weeds were established at five sites. Since most of the critical problem areas in the Colorado Basin are on BLM lands, cooperative studies on these lands were discussed with an agreed to with the regional officers of the Soil and Moisture section of the BLM in the Salt Lake office.

Preliminary reseeding studies were established at five places having the following site conditions:

1. Buckhorn Flats 18 miles east of Castledale--shadscale-saltbush cover; heavy, salty soil with loose topsoil; precipitation 7 inches; elevation 5,500 feet. In addition to usual methods, species plots were set out on an area treated with eccentric disks (pitting machine). This area is representative of the widely occurring shadscale type in separated swales.

2. Cisco, private fenced enclosure owned by Victor Murray--mat and Gardner saltbush cover; heavy salty soil; precipitation 6.5 inches; elevation 4,447 feet; representative of extensive mat saltbush range type.

3. Along Thompson-Valley City road 2½ miles south of Thompson--BLM enclosure #1, Shadscale-galleta cover; loose sandy soil; precipitation about 8 inches; elevation about 5,000 feet; representative of extensive shadscale range type.

4. Northern edge of Mustang Basin 6 miles north of Blanding--burned area in heavy cover of pinyon-juniper with little understory; shallow sandy loam soil underlain with rocks often showing at surface; precipitation about 13 inches; elevation 6,500 feet; representative of extensive pinyon-juniper range type.

5. Grand Flats west of Bears Ears near Blanding-Hite road--juniper-sagebrush cover; undercover seriously depleted; sandy silt-loam soil; precipitation about 15 inches; elevation 8,000 feet; representative of extensive area of juniper-sagebrush where juniper is noticeably thickening the stand. Little forage now available to cattle; capable of producing good reseeding stands of grass and perhaps shrubs. Juniper would have to be removed in places. Soil and climate favorable for large-scale reseeding after removal of juniper-sagebrush cover.

METHODS OF REMOVING COMPETITION

Studies of the past few years have been made to learn the facts about various methods of plant control. Most attention has been directed toward means of controlling or removing brush in preparation for artificial revegetation. Study has also been directed toward learning more about controlling brush in native stands where a good understory of native grasses still exists.

Mechanical control and burning have been discussed rather fully in previous Station annual reports and will be treated briefly here. Chemical control, which is more recent, and in which field much work is being done currently, is discussed more fully.

Chemical Sprays For Removing Competition

Continuing studies point out several conditions under which the use of selective phytocides is desirable for the control of certain types of brush and weeds. On areas which for one reason or another cannot be burned or plowed, chemicals can usually be used to control the brush. They are also useful on native ranges where overgrazing has favored the increase of sagebrush and rabbitbrush and left only a scattering of grasses, and on reseeded areas where undesirable brush has invaded.

Results of chemical spraying on native range.--In a study at Moon Canyon on the Wasatch National Forest near Kamas, Utah, brush was sprayed with 2,4-D at the rate of 3.8 pounds and 6.4 pounds acid equivalent per acre. After big sagebrush (Artemisia tridentata) kills ranging from 96.5 percent to 97.5 percent and rubber rabbitbrush (Chrysothamnus nauseosus) kills ranging from 39.5 percent to 72.7 percent, the grass herbage yields were from 450 to 600 pounds per acre. This herbage production was obtained from the same grass types (Stipa spp.) which were producing 180 pounds per acre on adjacent unsprayed check plots in native range.

Results of chemical spraying on reseeded range.--In another study at Moon Canyon plots were established on reseeded range where big sagebrush and rubber rabbitbrush were invading. Plots were sprayed with 2,4-D at the rates of 3.8 pounds and 6.4 pounds of acid equivalent per acre. Kills in big sagebrush ranged from 87.5 to 92.9 percent and from 84.5 to 95.5 percent in the rubber rabbitbrush. Herbage production of grasses ranged from 5,000 to 6,000 pounds dry weight per acre on the sprayed plots after reduction of the brush. Adjacent plots which were not sprayed produced 2,500 pounds of herbage (grass) per acre.

Wyethia control in Idaho.--On the Targhee National Forest studies were established on mountain meadows where wyethia (Wyethia amplexicaulis and W. helianthoides) was crowding out grass species. The use of 2,4-D at the rate of 2 pounds acid equivalent per acre was effective in controlling up to 95 percent of the wyethia when applied between "first- and half-bloom." Control of the wyethia permitted an increase of 326 percent in yield of native grasses on treated plots over check plots.

Moldboard plowing was also tried and was found to destroy 75 percent of the wyethia. After reseeding, plowed plots produced 13 times as much grass as unplowed check plots. Moldboard plowing is expensive and is limited to fairly rock-free soils.

Quantitative studies in use of chemical sprays.--On the Pines reseeding area in the Dixie National Forest, two studies involving amounts of chemicals needed to control sagebrush and rabbitbrush are being continued. One study in a reseeded area is on a site where invading big sagebrush and rubber rabbitbrush are vigorous and robust, reaching a size of 4 feet or more in height and so dense in growth that the understory of grass is scarcely available to livestock. Plots were sprayed with 2,4-D at rates varying from 3/4 pound of acid equivalent per acre to 2 pounds acid equivalent per acre and with a formulation consisting of 2 parts 2,4-D to 1 part 2,4,5-T, rates varying from 3/4 pound to 2 pounds of acid equivalent per acre. Degree of injury of the brush species studied is shown in table 9. Highest kills and greatest degree of injury of brush were obtained with a mixture of 2,4-D and 2,4,5-T applied at 1-1/3 and 2/3 pounds per acre.

Effect of chemical sprays at different plant stages.--Near Paradise Valley, Nevada a series of study plots were established to determine growth periods during which rubber rabbitbrush is most susceptible to chemical spray application. Work was done in cooperation with the Humboldt and Toiyabe National Forests and the Nevada Agricultural Extension Service. Solutions of 2,4-D, 2,4,5-T and a mixture of 2,4-D

Table 9. Degree of injury of three brush species sprayed with various chemical solutions at Linford Area, Pines Reseeding project, Dixie National Forest

Chemical formulation and degree of injury	Rubber rabbit-brush	Big sage-brush	Black sage-brush
	Pct.	Pct.	Pct.
2,4-D, 3/4 lb./acre			
Dead	7.5	0.0	(1/)
Injured	42.5	10.0	
Not affected	50.0	90.0	
2,4-D, 1 lb./acre			
Dead	20.0	0.0	5.0
Injured	70.0	20.0	20.0
Not affected	10.0	80.0	75.0
2,4-D, 2 lbs./acre			
Dead	27.5	0.0	25.0
Injured	72.5	30.0	65.0
Not affected	0.0	70.0	10.0
2,4-D, 1/2 lb./acre 2,4,5-T, 1/4 lb./acre			
Dead	12.5	2.5	15.0
Injured	77.5	15.0	35.0
Not affected	10.0	82.5	50.0
2,4-D, 2/3 lb./acre 2,4,5-T, 1/3 lb./acre			
Dead	27.5	20.0	50.0
Injured	72.5	22.5	50.0
Not affected	0.0	57.5	0.0
2,4-D, 1-1/3 lb./acre 2,4,5-T, 2/3 lb./acre			
Dead	32.5	50.0	90.0
Injured	67.5	50.0	10.0
Not affected	0.0	0.0	0.0

1/ Not present in plot.

plus 2,4,5-T were used. Leaf development (expressed in percentages) was used as an indicator of the stages of growth. Branches of rabbitbrush having full leaf growth were cut in 1949 and used as a basis of estimating leaf development in 1950. Percentages were estimated and recorded for each plot sprayed. In November the proportion of plants apparently killed was estimated. An array suggested three stages within which the brush-kill data could be tentatively grouped:

I - up to 40 percent leaf development - initial stage
II - 45 to 80 percent leaf development - midseason stage
III - 80 percent and over - mature leaf stage

Rabbitbrush sprayed when plants are in the initial stage suffers moderate to little damage. The chemicals will cause leaves to wither and drop off and probably cause considerable stem curling. The number of plants that actually die makes spraying in this period uneconomical.

Sprayings during the midseason stage of leaf development were highly successful in killing rabbitbrush. At 1.5 pounds acid equivalent per acre, straight 2,4-D sprayed on plants at 60 and 80 percent leaf development gave brush kills of virtually 100 percent. It thus appears that, when rabbitbrush is sprayed carefully at the proper season, there is no advantage in using the more expensive spray solutions.

Immediately after plants reached the mature leaf stage, all spray solutions began to lose their effectiveness. Translocation of the chemical within the plant was so reduced after leaves had reached or nearly reached their full growth that very little killing resulted.

One point of interest in connection with spray efficiency correlated to stages of leaf development is that in every case the use of 2,4-5-T straight or in mixture with 2,4-D gave greater kills in the initial stage and in the mature stage than did 2,4-D straight.

Variety of chemicals tested for brush control.--A study on the Cache National Forest at Snow Basin (elevation 6,540 feet) near Ogden, Utah was designed to test the effect of three different rates of application of four different chemicals and one mixture of two chemicals. A series of replicated plots and checks were established in an opening in the aspen type where big sagebrush was intermingled with mountain snowberry (Symphoricarpos oreophilus). These plots were sprayed in mid-July, 1950 when spring flowering plants were in blossom and sagebrush and snowberry were growing vigorously. The kinds of chemicals and formulations used and the average percentage and degree of injury when observed in November, 1950 are shown in table 10.

Mechanical Brush Control

Many types of equipment have been studied in regard to their ability to control brush under conditions existing in the Intermountain region. The most successful mechanical implements and those which have had widespread acceptance have been the wheatland plow, the Dixie harrow, and, more recently, the brushland plow.

In Nevada, a 145-acre area having a stand of sagebrush was plowed with a wheatland plow which killed an average of 84 percent of the sagebrush. In 1945 this area was planted to crested wheatgrass and in June 1950 produced feed at the rate of 900 pounds per acre on a dry-weight basis. On such a range, cattle gain from 2½ to 3 pounds per day per animal during the grazing season.

Other miscellaneous implements including such equipment as offset disk harrows, disk plows, moldboard plows, rails, spike-tooth harrows, and other farm implements can be used for certain jobs in brush removal

Table 10. Degree of injury of big sagebrush and mountain snowberry sprayed with various chemical solutions at Snow Basin near Ogden, Utah (averages from duplicate plots)

Kind of chemical and rate applied per acre	Big sagebrush			Mountain snowberry		
	Degree of injury			Degree of injury		
	Dead	Badly injured	Little injured	Dead	Badly injured	Little injured
			Percent			
2,4,5-T--1 lb.	0.0	30.0	70.0	25.0	75.0	0.0
2,4,5-T--2 lbs.	10.0	90.0	0.0	37.5	62.5	0.0
2,4,5-T--3 lbs.	27.5	72.5	0.0	45.0	55.0	0.0
Dinitro amyl phenol--1 qt.	22.5	77.5	0.0	0.0	100.0	0.0
Dinitro amyl phenol--2 qts.	35.0	65.0	0.0	0.0	100.0	0.0
Dinitro amyl phenol--3 qts.	70.0	30.0	0.0	0.0	100.0	0.0
2,4-D --2/3 lb.) 2,4,5-T--1/3 lb.)	0.0	0.0	100.0	12.5	37.5	50.0
2,4-D --1-1/3 lbs.) 2,4,5-T-- 2/3 lb.)	12.5	87.5	0.0	52.5	47.5	0.0
2,4-D --2 lbs.) 2,4,5-T--1 lb.)	30.0	70.0	0.0	87.5	12.5	0.0
Pentachlorophenol--4 gal.	0.0	100.0	0.0	5.0	95.0	0.0
Pentachlorophenol--8 gal.	25.0	75.0	0.0	7.5	92.5	0.0
Pentachlorophenol--12 gal.	55.0	45.0	0.0	0.0	100.0	0.0
2,4-D--1 lb.	2.5	97.5	0.0	10.0	90.0	0.0
2,4-D--2 lbs.	5.0	95.0	0.0	25.0	75.0	0.0
2,4-D--3 lbs.	30.0	70.0	0.0	62.5	37.5	0.0

and seedbed preparation. Factors governing their use include availability, type of work to be done, costs, but mostly relative effectiveness in brush eradication.

At Buttermilk Creek in Nevada, a sagebrush range was railed with a 3-section railroad iron drag in 1945. This railing on 426 acres resulted in killing 59 percent of the sagebrush. The area was seeded to crested wheatgrass in 1946 and in 1950 produced feed at the rate of 200 pounds per acre, dry weight.

Controlled Burning

The use of fire to control brush has many advantages. Large areas, when burned under proper conditions, can be cleared at a very low cost. The ashes make an ideal seedbed, the debris which often hampers seeding operations is absent, and most competition is eliminated. Larger species of mountain brush, such as chokecherry or oakbrush which are too large for control by mechanical means, are readily controlled by burning. Many administrators of public lands, however, are reluctant to use fire for fear of its uncontrolled spread. Then too, on many ranges, the ideal time for burning is the season of highest hazard. The careless use of fire or uncontrolled burning can result in great destruction both on range and in the forest. The complete loss of litter and the destruction of a high percentage of organic matter and the consequent effect on water infiltration and runoff must be considered. On soils subject to blowing, the use of fire is dangerous since it opens the area to wind erosion.

Use of fire in juniper-pinyon type.--Studies in central Utah show that land now supporting heavy stands of Utah juniper and pinyon pine can be made productive for grazing by seeding to adapted grasses. However, competition from the trees must first be removed. Grass plants remain small and herbage production is usually less than 50 pounds per acre where trees are not killed prior to seeding.

Tests in 1950 showed that a pneumatic flame thrower was very suitable for burning trees on this type of land. This back-pack flame thrower is easily carried by one man. The pistol grip handle is convenient for controlling the flame.

Another pump with flame thrower attachment was also satisfactory for burning trees but was difficult and cumbersome to transport, which slowed up the burning process. Two men were needed to carry the pump and a third to operate the burner for most efficient work. This pump was also more hazardous than the 1-man pneumatic burner.

Attempts at large-scale burning on juniper land were not satisfactory in 1950. It is believed this was due to weather conditions and the fact there was no understory of vegetation to help carry the fire. Heavy spring grazing had eliminated the cheatgrass which otherwise would have helped carry the fire between trees. Further burning tests are planned on this land for the coming year.

The fire line around this area was cleared with a D-6 caterpillar tractor with bulldozer attachment. A private operator hired the work done at a cost of $10.00 per hour. Ten hours were required to clear trees from 2 miles of fire line 70 feet in width. A total of 16.96 acres were cleared along the fire line at a cost of $5.96 per acre of cleared land. The increased yields resulting from seeding adapted grasses indicate that moderate expense is justified in clearing and seeding this type of land. On areas where juniper trees are now invading it is most economical to cut out the young trees with an axe before they become mature. Land should be seeded soon after clearing to prevent weeds and other undesirable species from invading.

The following tabulation shows yields and stand ratings of the best 15 our of 50 species planted in range plots on burned juniper land in 1943. Species are listed in order of highest average yields over the past 4 years. Plot ratings are those for 1950. The average annual precipitation is estimated to be between 12 and 13 inches at this site.

Species	Dry wt. yield Lbs./acre	Plot rating
Elymus condensatus	1,377	10
Agropyron elongatum	1,335	10
Agropyron intermedium	1,249	10
Agropyron trichophorum	1,145	10
Agropyron cristatum	1,000	10
Agropyron sibericum	957	10
Agropyron inerme	942	10
Agropyron spicatum	895	8
Elymus junceus	638	10
Elymus triticoides simplex	590	8
Calamagrostis epigeios	559	8
Oryzopsis hymenoides	500	8
Agropyron smithi	494	8
Elymus chinensis	437	7

METHODS OF REVEGETATION

After a seedbed has been prepared and competing species have been controlled, areas to be revegetated are usually seeded by such conventional methods as drilling or broadcasting. On some sites where desirable native grasses persist, the remnants can increase naturally if given the proper protection. There are many areas, however, where these usual procedures cannot be followed. On such sites, many of which are critical from an erosion standpoint, extraordinary methods for establishing plant cover are being studied and are discussed briefly here.

Use of mulches on granitic soils.--The granitic soils of southwestern Idaho are loose, coarse, readily eroded, and low in moisture-retaining ability. The south-facing slopes in the foothills are mainly covered with cheatgrass, a type erratic in production of herbage for ground cover. Artificial revegetation will be needed on much of the area if the present annual contribution of silt to the Boise River is to be reduced. During the past 15 years tests have been made of the adaptability of several species for use on this land, and different methods of reseeding some of the more promising have been tried. As yet, a successful method of artificially restoring perennial vegetation to these slopes has not been discovered.

The steep slopes are bound to make any rehabilitation program difficult. The exposure of the slopes to the direct rays of the sun, along with the low moisture-holding capacity of the soil, makes it difficult for many seedlings to survive for more than a few weeks in the spring. The very high soil temperatures, even in April, hasten the loss of soil moisture by evaporation, and also have a direct effect on the growth and survival of seedlings. The depleted soils are low in organic content and deficient in nitrogen, but their very droughty nature makes the application of commercial fertilizers to stimulate the growth rate of the seedlings hazardous.

Recent studies show that a light mulch of straw or hay, by moderating the heat of direct sunlight and reducing the air movement near the ground surface, enhances the growth rate of plants, grass seedlings, or weeds and delays for a time the usual early mortality of seedlings. More observations are needed to determine whether enough time can be gained to get the seedlings through the crucial first season.

Cheatgrass litter mulches.--The use of cheatgrass litter as mulch is being studied on granitic slopes. In those years when cheatgrass (Bromus tectorum) produces abundant herbage, the litter of that year might serve as natural mulch. The use of cheatgrass is advantageous inasmuch as it is produced naturally, does not have to be transported to the site, nor does it require distribution. It protects the soil surface from erosion by promoting the infiltration rate of the soil and since it is more or less stable, is also instrumental in decreasing soil movement. A cheatgrass mulch also protects the soil from insolation and tends to favor reseeded species. Chemical sprays to kill cheatgrass before seed is formed have been tried with varying degrees of success in 1948, 1949, and 1950. Chemical control of cheatgrass is being tested further in connection with a method of seeding study to learn how to plant with minimum disturbance in the resultant natural mulch.

Tests with commercial fertilizers.--Commercial fertilizer studies in preliminary trials in northwestern Utah and southern Idaho show no effects from phosphate but increased volume of top growth from nitrogen. For example, a carefully conducted experiment on Farmington Flats, Wasatch National Forest, showed no visible effect from treble superphosphate at the rate of 200 pounds per acre. Ammonium sulfate at the same rate did not affect the stand of grass but increased the size of plants by 2½ times for the first summer, and about 30 percent the second summer. Farmyard manure increased the size of plants by more than three times for 3 years on a badly eroded area covered with tarweed which had been harrowed twice with a spring-tooth harrow and seeded to smooth brome, tall oat, and crested wheatgrass. This effect seems likely to continue for several more years.

In Paulsin Basin, also on the Wasatch Forest, the forest ranger treated an eroded tarweed area by harrowing, fertilizing, and seeding. He reports no effect from phosphate, but increased germination and volume of growth from nitrogen. No figures were recorded. Increased volume of growth has also been reported in similar studies on the Manti and Uinta National Forests in Utah, and on the Boise Forest in Idaho. In Idaho the summers were so dry that neither good stands nor growth have been obtained from seedings made at the time fertilizers were applied.

Shrubs for revegetating severe sites.--Until 1950 all reseeding efforts on the critical parts of the granitic foothills were directed toward restoration of forage species, principally perennial grass, which is probably the climax type on most of the area. Grasses, although excellent watershed cover, may not be as well adapted as certain other kinds of plants are for survival on soils as badly depleted as these.

It has been noticed that some native shrubs and semishrubs are adapted for establishment on what appear to be very severe sites, and certain of these have growth habits that make them desirable as watershed protectors, although they are not very palatable to livestock. Among them are Ceanothus velutinus and Eriogonum umbellatum. Tests are now in progress to determine how to get these, and other species previously tried, established.

Rhizome planting.--Exploratory rhizome plantings have been made on dry, badly eroded south-facing slopes in central Utah. The tests are designed to determine the adaptability of rhizomatous species to such sites and the practicability of this method of planting, which may otherwise have limited application, on small areas to aid in watershed management and gully control. Rhizome plantings were made at three locations on the Manti-La Sal Forest in 1950: (1) Eight selected species were planted on a dry south-facing shale slope in the lower limits of the mountain brush type; (2) a planting of 12 selected species was made on seriously depleted south and southwest slopes in the mountain brush type; and (3) 12 selected species were planted on a depleted south slope and also on a depleted north slope in the subalpine zone.

Germination of pelleted and unpelleted seed.--While the difference in germination between seed pelleted by a commercial coating process and untreated seed was generally quite small, preliminary results show that pelleting is generally detrimental to seed germination. Percent germination is as follows:

Species	Untreated seed	Seed in pellets
Crested wheatgrass	94.5	92.5
Intermediate wheatgrass	86.2	75.2
Orchardgrass	79.8	53.4
Smooth brome	77.5	67.2
Timothy	94.7	95.2
Yellow sweetclover	1/86.2	1/75.2

1/ Includes hard seed.

Field emergence tests made during the spring of 1950 substantiate the results from the germination tests.

Revegetation for watershed management.--Prevention of destructive floods is one of the chief problems for watershed management in the Intermountain region. These floods usually originate on relatively small but seriously depleted subalpine ranges. Where a serious problem exists the only permanent control is by the establishment of a suitable vegetative cover.

In 1950 administrative plantings were made on approximately 100 acres in Dry Pole Fork on the Manti-La Sal National Forest which had been double disked to remove the undesirable native competition in a sweet sagebrush type. The area was contoured at approximate 50-foot horizontal intervals and most of the area was broadcast to a mixture of recommended species. The Intermountain Station made an adaptability test of 12 selected species on part of this area. Three planting treatments were applied for each species as follows: furrow planting and covering; broadcasting and harrowing; and broadcasting in plow furrows without covering.

The same seed mixture was also broadcast on a depleted rocky sidehill and covered by raking. A similar depleted area on which the soil had been recently disturbed by sheep was broadcast to an adapted strain of mountain brome at a rate of 25 pounds per acre. Preliminary results of all plantings will be gathered during and after the 1951 growing season.

Water spreading on reseeded land.--There are several thousand acres of sagebrush land in Garfield County, Utah, within a precipitation belt of 8 to 12 inches. Big sagebrush (*Artemisia tridentata*), or black sagebrush (*A. nova*), composes the predominant brush cover. If this depleted sagebrush range can be successfully seeded to crested wheatgrass or similar species, the value of spring-fall ranges within short distances of the ranches would be greatly increased. In addition, the demand on meadows and alfalfa fields as well as on summer and winter ranges would be reduced.

Certain of these depleted spring-fall areas could be supplied with one or two irrigations in periods of high water. This would greatly increase the amount of forage produced. With these points in mind an experimental demonstration area was set up in cooperation with the Garfield County U.S.D.A. Council.

Ten acres of privately owned land, approximately 4 miles northeast of Panguitch, was selected. Half of this area was planted with a drill in mid-April 1950 to 9 species and a mixture. Surplus water was applied to the land immediately after seeding and during the spring when it was available. All of the species planted produced good to very good stands. All species made excellent herbage and root growth and 5 of the 9 species produced seed heads during their first growing season. It is planned that this 5-acre tract will be irrigated with surplus early spring water in subsequent years. The 5-acre dry land area was planted with a drill on November 10, 1950 to 14 promising species and a mixture. Results of the plantings on both areas will be compared in subsequent years.

SITE FACTORS

The suitability of more than 500 species and strains for artificial revegetation has been tested in central Utah over the past 10 years. Primary testing places have been in nurseries representative of four major plant formations, all within an 11-mile distance. These are at Sorenson's field south of Ephraim, elevation 5,500 feet, precipitation 10.5 inches (sagebrush zone); Majors Flat in Ephraim Canyon, elevation 7,100 feet, precipitation 15 inches (oakbrush zone); Headquarters, Ephraim Canyon, elevation 8,850 feet, precipitation 29 inches (aspen zone); Summit enclosure, elevation 10,200 feet, precipitation 30 inches (subalpine zone). Whereas a large number of species and strains have proved unadapted in each zone, others have maintained good stands and shown outstanding yields after 10 year's trial.

From 23 to 25 grass species and 10 to 20 species of legumes and forbs are listed in table 11 for each zone from those previously found suitable. Figures show the average yield of the past 4 years. This 4-year average is more representative than 1 year's data because yields fluctuate widely with growing conditions in different years. The plot ratings shown in the table are the final ones at the end of the 10-year period.

In addition to the species listed, several others show promise. They were not compared in the table because 10 year's data were not yet available for them. Among these are Agropyron amurense, Bromus tomentellus, and Agropyron pungens in the oakbrush and aspen zones, and Bromus tomentellus and Alopecurus pratense in the subalpine.

PLANT BREEDING

Strains of species useful in reseeding have been collected, or obtained from the SCS grass nursery at Pullman, the BPISAE Seed Introduction Division, or the Western Grass Breeding project. In all, more than 400 strains have been obtained, about 110 during 1950. All of these were selected as being superior to the stock variety from which they were selected.

At Majors Flat in Ephraim Canyon, 90 strains were tested for comparative yield during 1950 (table 12). The forage production results when arranged in order also provide a good measure of the suitability of species. It seems likely that future work should be with the species whose strains are in the upper half of the list. The tests should include various kinds of sites since, for example, the highest yielding strain of Bromus carinatus at Majors Flat winter-killed in the subalpine zone.

Dr. Wesley Keller in charge of grass breeding for the BPISAE at Logan, Utah cooperates fully and furnishes whatever promising strains he develops.

UTILIZATION

Cattle Grazing - Benmore, Utah

The cattle grazing studies at Benmore involve four methods of grazing, each at three intensities. The study was described rather fully in the 1947 annual report and progress accounts were presented in the 1948 and 1949 reports. Very briefly, the experiment is being conducted on 24 pastures of 100 acres each, divided into two blocks of 12 pastures. The blocks include four methods of grazing at light, moderate, and heavy intensities, as follows: All spring, continuous; all spring, rotation; 10 day-deferred; and 10 days short at end.

Table 11. Air-dry herbage yields of grasses and forbs within four planting zones near Ephraim, Utah together with plot ratings[1] (average 1947-50)

Species	Sagebrush zone	Oakbrush zone	Aspen zone	Subalpine zone
	Lbs./acre	Lbs./acre	Lbs./acre	Lbs./acre
Grasses				
Agropyron cristatum	2,955(8)	2,778(10)	-	-
A. dasystachyum	1,500(4)	-	-	1,600(8)
A. elongatum	2,070(4)	3,781(7)	-	-
A. inerme	3,330(7)	3,259(8)	-	-
A. intermedium	2,373(7)	4,075(10)	12,450(10)	4,281(8)
A. riparium	2,007(9)	-	-	-
A. sibericum	-	2,766(10)	-	-
A. smithi	1,080(8)	-	5,688(10)	1,150(8)
A. spicatum	3,731(7)	3,062(8)	-	-
A. subsecundum	-	-	3,050(10)	1,388(4)
A. trachycaulum	-	2,485(9)	2,694(9)	1,803(6)
A. trichophorum	2,096(9)	4,025(10)	10,672(10)	-
Agrostis alba	-	-	-	2,950(6)
Arrhenatherum elatius	-	2,475(8)	7,360(10)	3,778(8)
Bromus carinatus	-	-	4,459(10)	3,203(10)
B. erectus	-	2,625(6)	10,625(10)	-
B. inermis	1,481(6)	-	10,625(10)	5,553(10)
Calamagrostis epigeios	1,380(9)	2,746(10)	11,950(10)	2,975(10)
Dactylis glomerata	-	-	7,309(10)	3,306(7)
Elymus canadensis	-	-	2,888(6)	-
E. condensatus	2,550(4)	16,544(8)	23,062(9)	7,972(7)
E. giganteus	-	5,734(10)	-	-
E. glaucus	1,524(3)	3,775(10)	2,538(6)	1,256(2)
E. junceus	5,162(9)	3,572(9)	-	1,469(2)
E. triticoides	1,725(7)	5,112(10)	-	3,384(10)
E. triticoides simplex	4,792(5)	4,000(6)	-	-
Festuca elatior	-	-	-	2,050(6)
F. elatior arundinacea	-	2,462(6)	5,240(8)	-
F. kingi	-	-	2,813(6)	-
F. rubra	-	-	-	1,929(7)
Hordeum bulbosum	2,606(5)	3,975(7)	8,312(10)	1,972(3)
H. nodosum	-	-	2,884(10)	2,048(8)
Oryzopsis hymenoides	845(3)	-	-	-
Phalaris arundinacea	-	4,625(10)	14,450(10)	5,376(6)
Phleum pratense	-	-	6,766(9)	2,852(6)
Poa ampla	2,149(5)	-	-	-
P. pratensis	-	-	-	2,073(8)
Secale montanum	-	2,988(10)	-	-
Sitanion hystrix	1,087(3)	-	-	-
Stipa columbiana	-	2,769(8)	3,673(8)	1,818(7)
S. comata	1,257(3)	-	-	-
S. lettermani	-	-	2,284(10)	1,551(7)
S. occidentalis	-	2,559(7)	-	-
S. robusta	1,391(4)	2,694(4)	3,016(6)	-
S. viridula	-	2,838(9)	2,959(8)	-

Table 11. (Continued)

Species	Sagebrush zone	Oakbrush zone	Aspen zone	Subalpine zone
	Lbs./acre	Lbs./acre	Lbs./acre	Lbs./acre
Forbs				
Agastache urticifolia	-	1,697(3)	3,242(4)	-
Angelica wheeleri	-	-	-	573(4)
Astragalus chinensis	-	-	1,447(4)	-
A. cicer	440(2)	9,314(10)	12,228(10)	2,202(6)
A. falcatus	1,100(3)	12,202(9)	4,047(4)	-
Balsamorhiza sagittata	387(5)	-	5,775(10)	-
Clematis ligusticifolia	-	2,074(4)	-	-
Geranium viscosissimum	-	-	-	3,143(8)
Hedysarum boreale utahense	-	1,842(7)	-	-
Helianthella uniflora	-	-	1,665(4)	-
Heracleum lanatum	-	-	-	3,631(2)
Lathyrus sylvestris	887(3)	7,168(8)	-	238(1)
Lomatium simplex	-	-	1,634(9)	-
Lotus corniculatus	-	-	8,006(10)	-
Lupinus alpestris	-	-	-	1,302(5)
L. argenteus	-	2,301(8)	-	-
L. caudatus	-	1,247(5)	-	-
L. palmeri	-	1,422(7)	-	-
L. spathulatus	-	2,782(6)	991(6)	-
Medicago falcata	-	3,128(8)	-	-
M. glutinosa	2,862(7)	5,167(9)	-	-
M. sativa	2,862(7)	5,644(10)	-	2,901(3)
Melilotus alba	-	-	982(3)	-
M. officinalis	-	-	3,299(2)	-
Onobrychis grandis	-	3,412(6)	-	-
O. sativa	1,270(4)	2,459(7)	-	-
O. vulgaris	1,350(6)	3,765(8)	-	-
Osmorhiza occidentalis	-	-	1,802(7)	446(2)
Penstemon cyananthus	-	-	1,919(6)	-
P. palmeri	2,552(4)	-	-	-
P. rydbergi	-	-	1,118(6)	1,051(6)
Rudbeckia occidentalis	-	-	9,100(6)	2,058(3)
Sanguisorba minor	1,625(3)	1,789(7)	-	-
Senecio serra	-	-	12,381(6)	-
Sphaeralcea rivularis	-	2,946(6)	4,643(9)	1,700(4)
Trifolium fragiferum	-	-	1,567(4)	-
T. hybridum	-	-	-	1,450(6)
T. pratense	-	1,418(4)	2,287(6)	611(2)
T. repens	-	-	-	840(3)
Vicia tenuifolia	-	1,459(6)	-	-
Viguiera multiflora	-	-	5,447(9)	2,898(8)

1/ Plot ratings (in parentheses) are based on number and distribution of plants: 1-2 very poor; 3-4 poor; 5-6 medium; 7-8 good; 9-10 very good.

Table 12. Air-dry herbage production from strains of 16 grass species, Majors Flat, 1950

Species	Number of selections or strains included	Average yield of all selections Lbs./acre	Yield of highest producing selection Lbs./acre	Yield of lowest producing selection Lbs./acre
Agropyron elongatum	3	6,118	6,312	5,835
A. intermedium	8	3,940	4,625	3,600
A. trichophorum	7	3,632	3,975	3,325
A. trachycaulum	2	3,187	3,325	3,050
Bromus carinatus	6	3,135	4,325	2,062
Agropyron cristatum	13	2,956	3,875	1,800
Bromus inermis	15	2,700	3,600	1,275
Agropyron inerme	8	2,655	3,050	2,100
A. spicatum	6	2,613	3,025	2,350
Elymus canadensis	2	2,406	2,437	2,375
Stipa viridula	2	2,300	2,550	2,050
Festuca elatior arundinacea	4	2,287	2,375	2,175
Elymus junceus	3	2,046	2,250	1,987
Dactylis glomerata	5	1,810	2,050	1,550
Agropyron smithi	3	1,792	1,962	1,680
Festuca rubra	3	245	312	180

During 1950, the planned intensities of grazing of 50, 65, and 80 percent use for light, moderate, and heavy intensities were achieved rather closely. The average of eight pastures for each intensity showed 54.0, 65.5, and 82.1 percent use. This was a year of low production and hence a year with a tendency to overuse. With spring precipitation somewhat less than average, dry-weight yields of crested wheatgrass on pastures used for light, moderate, and heavy grazing, respectively, were 496, 470, and 533 pounds as compared with 861, 931, and 830 pounds per acre in 1949.

Heavy grazing has materially reduced the daily gains of mature cattle but has not affected those of calves. The average daily gain in live weight of cattle in all pastures grazed lightly, moderately, and heavily was 2.55, 2.17, and 1.67 pounds per head per day. The methods of grazing have not settled into a continuous pattern of response. In 1949, there were indications that rotation grazing produced the most beef per acre, but in 1950 it was exceeded by all of the three other methods. Probably none of these differences are significant, as they are fluctuating greatly between years.

Movement of soil, both during heavy rain and by heavy winds when the soil was dry, was noticeable on the heavily grazed pastures and on spots of the lightly grazed ones. No such movement was observed on the moderately grazed pastures. Heavy grazing removed too much of the grass over most of the pastures. Under light grazing some areas were little used and the plants produced numerous seed stalks. Later the cattle avoided these spots and concentrated on the previously grazed areas, overgrazing some of them. Under moderate use the pastures were more uniformly grazed.

Daily cattle gains in spring also reflected the damaging effects of heavy grazing, both as an average and in all treatments (table 13). Gains under light and moderate grazing were practically the same. The last method of grazing, with the season shortened by 10 days at the end, gave the greatest difference from the other methods. This difference probably reflects the tendency for daily gains to be greatest early in the season. The influence of method of grazing on total beef production is shown in table 14.

Table 13. Average daily gains by cattle at three different intensities and under four methods of grazing, Benmore, spring 1950

Intensity	(Pounds per day)	Method	(Pounds per day)
Light	2.55	Rotation	1.80
Moderate	2.17	All spring (continuous)	2.19
Heavy grazing	1.67	10 days deferred	2.14
		10 days short at end	2.34

Table 14. Total pounds of beef produced in 100-acre pastures given different treatments, Benmore, spring 1950

Intensity	(Pounds per 100 acres)	Method	(Pounds per 100 acres)
Light	2,642	Rotation	2,533
Moderate	2,850	All spring (continuous)	2,974
Heavy	2,899	10 days deferred	2,868
		10 days short at end	2,796

The climatic and grazing conditions at Benmore bring out more and more clearly that crested wheatgrass is the most desirable species for such an area. When the pastures were seeded, small proportions of smooth brome, slender wheatgrass, bulbous bluegrass, and western wheatgrass were included. Smooth brome and slender wheatgrass do not now appear in the pastures. Cheatgrass occupies bare spots, but is being reduced year by year as crested wheatgrass spreads. A little *Sitanion* and a few weeds occur in spots of hard soil or on disturbed areas. Cattle clearly prefer crested wheatgrass for spring and early summer feed as is shown by the comparison of herbage produced and forage taken from crested wheatgrass, as follows:

	Herbage produced Pct.	Forage taken Pct.
Light grazing	86.9	94.4
Moderate grazing	92.4	96.1
Heavy grazing	93.9	96.2

During 3 years, there has been in all of the pastures in the study an increase of 9 percent in the number of grass plants per unit area and an increase in density of 46 percent. The increase in density is a joint result of the increase in number of plants and the increase in the size of small plants. Of the plants listed as less than 1 inch in basal diameter in 1948, 47 percent had increased in diameter by 1950.

Intensity of grazing markedly affects the number of crested wheatgrass plants that escape grazing because of old stiff seed stalks being left unused (wolf plants). Under light grazing the number of plants ungrazed because of old growth increased by 280 percent. The amount of old growth increased 108 percent by weight. Under moderate grazing these respective figures were 12 percent and 2.4 percent. Under heavy grazing, the number of plants decreased 76 percent and the weight of old growth decreased 68 percent. Here is a slight indication that utilization of 65 percent (moderate) is a bit too light so far as the plants of crested wheatgrass are concerned.

There is a slow but apparently persistent increase in both rubber rabbitbrush and big sagebrush in the pastures. In 3 years rabbitbrush has increased in two ways: (1) it occurs now on 19 percent of the plots instead of on 14 percent; and (2) the plots that have been invaded have nine more plants per 100 square feet. The number of sagebrush-infested plots increased from 8 to 9 percent and the number of new plants per 100 feet increased by two plants. The infestation is not heavy except in two pastures but it is increasing. No evidence is discernible that response differs with intensity of grazing--and two-thirds of the pasture are not being overgrazed.

Sheep Grazing, Ephraim, Utah

Comparison of crested wheatgrass and rye for sheep pasture.--To determine the comparative value of rye and crested wheatgrass for spring-fall pasture, sheep have been grazed on comparable pastures at Ephraim, Utah, for the past 7 years. For the first 3 years, the 5.8-acre rye pasture was compared to a 6-acre crested wheatgrass pasture. In 1944 the crested wheatgrass pasture was enlarged and divided into six 1½-acre pastures. Three of these pastures (1, 3, and 6) have been grazed concurrently in the spring with the rye pasture and their composite response has been compared with that of the rye pastures.

The crested wheatgrass was planted in the fall of 1940 and the rye was planted in the fall of 1942. Since the rye is an annual grass good seed must be produced each year. Except for two years the pasture has been disked in the fall to insure a good grass stand the following year.

Each spring from 10 to 16 ewes with single new-born lambs have grazed the rye. In 1950 because of the lack of enough ewes with single lambs, 9 of 13 ewes were put in the rye pasture with twin lambs. A comparable number of ewes and lambs have grazed the crested wheatgrass pastures each spring. The spring grazing period covers a 3- to 5-week period in the latter part of April and in May. The crested wheatgrass pastures have been grazed again in the fall of each year except during 1950. The rye pasture, however, provided fall grazing in only 3 of the 8 years.

Sheep month's use for both pastures during the 8 years is shown in table 15. While the rye has a slightly greater average grazing capacity per acre during the spring, the crested wheatgrass has produced four-tenths of a sheep month per acre more forage than the rye for the combined spring-fall periods. This study also shows that crested wheatgrass is more dependable from year to year than rye. The better grazing furnished in the fall establishes it as a superior pasture. However, the experiment does substantiate the fact that rye furnishes quick spring pasturage while perennial grasses are being established. Further, the study shows that with proper management rye pastures can be maintained in production for several years even when the annual precipitation is no more than 10 inches.

Table 15. Sheep month's use per acre on crested wheatgrass and rye pastures near Ephraim, Utah, 1943-50[1]

Year	Crested wheatgrass			Rye		
	Spring	Fall	Total	Spring	Fall	Total
1943	3.6	1.3	4.9	5.7	0.0	5.7
1944	4.9	2.2	7.1	5.2	3.1	8.3
1945	6.0	1.9	7.9	6.5	2.6	9.1
1946	4.3	1.4	5.7	2.9	0.0	2.9
1947	4.0	3.3	7.3	4.9	1.8	6.7
1948	4.5	0.9	5.4	3.9	0.0	3.9
1949	3.6	0.8	4.4	3.4	0.0	3.4
1950	3.4	0.0	3.4	3.6	0.0	3.6
Average	4.3	1.5	5.8	4.4	1.0	5.4

[1] 1950 figures on rye pasture on basis of ewes with single lambs.

The ewes and their lambs were weighed at the beginning and again at the end of each spring grazing period, except in 1945 when only the lambs were weighed. Sheep gains are shown in table 16. Lambs and ewes made very similar gains on the two types of forage. The differences in yearly gains by ewes and lambs are largely attributed to differences between sheep. The lambs averaged approximately one-half pound per day and the ewes averaged approximately one-third pound per day in both the crested wheatgrass and rye.

Effect of grazing intensity on crested wheatgrass.--Six pasture units of approximately 1½ acres each were fenced in the fall of 1944 on a stand of crested wheatgrass that was planted in the fall of 1940.

Table 16. Spring weight gains per day be lambs and ewes on crested wheatgrass and rye pastures near Ephraim, Utah, 1943-50

Year	Lambs		Ewes	
	Crested wheatgrass	Rye	Crested wheatgrass	Rye
	Pounds		Pounds	
1943	0.50	0.67	0.48	0.52
1944	0.48	0.63	0.47	0.50
1945	0.51	0.49	-	-
1946	0.54	0.56	0.17	0.17
1947	0.42	0.36	0.00	0.16
1948	0.57	0.55	0.19	0.38
1949	0.59	0.54	0.55	0.29
1950	0.68	1/0.75	0.13	1/0.09
Average	0.54	0.57	0.28	0.28

1/ Lamb gain per ewe (13 ewes and 21 lambs). Gain per individual lamb 0.48 pound per day.

A factorial design of spring grazing treatments and replication consists of three intensities of grazing, each replicated twice and two periods of spring grazing, each replicated three times. The intensities of grazing are: (1) light, approximately 50 percent utilization of crested wheatgrass by the end of spring grazing; (2) moderate, 70 percent utilization; and (3) heavy, approximately 90 percent utilization. The beginning of the two periods of spring use are: (1) at the date when stockmen in the vicinity begin grazing, and (2) at the date of range readiness, when leaf blades average approximately 4 to 5 inches in height. Beginning dates for the two periods generally differ by about 2 weeks.

To determine the relative merits of the three intensities of grazing and the two starting periods, ewes with single lambs have grazed the pastures during the spring for the years 1945 through 1950. There has been very little consistent change in the relative productivity of the pastures due to season or intensities of grazing. It may be that the deferred heavily grazed pasture is beginning to show a decline in the relative productivity. When the sheep were put in the pastures in the spring of 1950 the average height of grass was less, grass yields were smaller, and the number of annuals, especially Russianthistle, had increased in the heavily grazed pasture as compared to the lightly and moderately grazed pastures.

Sheep Grazing, Dubois, Idaho

Since 1941, two ½-acre pastures of crested wheatgrass on the U. S. Sheep Experiment Station have been grazed each year at the rate of five sheep months per acre. The grass is still vigorous and shows no sign of deterioration. The precipitation is about 11 inches per year and the elevation 5,500 feet. This is a highly satisfactory grazing capacity for an area with this low precipitation rate. One pasture is grazed about 2 weeks earlier than the other, but as yet no visible differences have been produced in the grass.

Production and Utilization On Seeded Areas

Table 17 gives production data for several large-scale seedings in Idaho and Nevada together with grazing capacities of several areas before and after seeding in Utah. Figures in the table supplement those given at the end of the reseeding section of the 1948 and 1949 annual reports.

Table 17. Air-dry herbage production of crested wheatgrass seedings in Idaho and Nevada, 1948-50, and grazing capacity before and after seeding of various areas in Utah

Location	Elevation	Precipitation	Area	Production		
				1948	1949	1950
	Feet	Inches	Acres		Lbs./A.	
Idaho						
Boise Nat. Forest						
Willow Creek	4,000	16	800	459	454	425
Cottonwood	3,800	19	50	450	828	805
Private land						
Orchard	3,500	12	1,200	655	339	410
Meadow Creek	5,300	14	20	-	-	1,096
Nevada						
Humboldt Nat. Forest						
Ruby Valley	6,200	15	815	-	1,403	850
Martin Creek	6,700	16	28	-	1,692	1,570
Dinner Station	5,500	11	327	-	392	301
Goosey Flat	6,500	11	958	-	607	668
Buttermilk	5,000	9	600	-	406	315
Private lands - Wells	5,800	11	400	-	830	1,250
BLM - Goats Corral	4,800	10	280	-	304	257
				Acres per animal-unit month		
Utah				Before seeding		After seeding
Cache Nat. Forest						
Mud Flat	6,500	15	700	10		4
Cabin Hollow	7,500	18	655	10		4
Wasatch Nat. Forest						
Moon Canyon	6,500	20	300	10		2
Manti Nat. Forest						
South Horn	8,000	10	310	16		3
La Sal Nat. Forest						
Dry Mesa	7,000	18	2,900	12		3
Fishlake Nat. Forest						
Lost Creek	7,500	18	2,433	12		3
Dixie Nat. Forest						
Pine Valley	6,700	12	40	17		2.5
Reed Ranch	7,500	12	690	10		1.5
Upper Grass Valley	8,000	11	400	15		1.5

HALOGETON

In several localities in southern Idaho, northeastern Nevada, and northwestern Utah the poisonous weed, halogeton (Halogeton glomeratus) has been increasing during the past 7 years. This arid range area has many sites where the soil is nearly bare between the dominant, relatively unpalatable shrubs. Past abuse has left very little of the grass originally present in the native cover. The bare areas offer ideal seedbeds for halogeton whose abundant seed is readily scattered by wind, moving vehicles, and animals.

Where it is abundant, halogeton has caused heavy livestock losses, particularly in the fall. Sheep probably eat it then because other forage is less abundant. Unfortunately, the plant appears to be most poisonous at this time and a sheep eating as little as 2 pounds of the plant usually dies in a few hours. The toxicity of the plant is due to its high content of oxalates which precipitate serum calcium from the blood. Cattle are also affected if they eat the plant.

The obvious remedy for this dangerous situation is to promote a better perennial cover either by artificial revegetation or by natural revegetation through moderate use. Increased cover would in a large measure prevent growth of halogeton or at least would provide other forage so that halogeton would not be eaten in large enough amounts to cause poisoning. As a result of studies conducted during the past several years, the Station has some concrete evidences of halogeton control.

Control of halogeton by perennial grasses.--Three different plantings have been made near Wells, Nevada to determine ability of perennial grasses to control the spread of halogeton. A burned-over (1944) sagebrush area was used for the experiment. Plantings were made in the fall of 1945, 1947, and 1949, drilling directly into the halogeton stands. Results showed that halogeton was not able to invade an area already occupied by crested wheatgrass. On the other hand, where crested wheatgrass was drilled into a dense stand of halogeton in 3 years no halogeton was found in the plot although it was present outside. On sites where crested wheatgrass is adapted, it can completely control halogeton.

Halogeton control in Idaho.--A study was initiated in 1949 to show the effect of halogeton upon the establishment of various species of grass that may be adapted to sites where halogeton was found growing. The effect that the adapted species may have upon the continuance or control of halogeton is also being studied. This study is being made in cooperation with a committee of local stockmen and representatives of Federal, State, and county agencies.

Chemical control of halogeton in Nevada.--Because of the long period that halogeton seed will germinate, chemical sprays have greater killing effect if applied toward the end of the rather long susceptible period. Studies indicate that this period extends until the plants start to lose their shiny green appearance. Chemicals have little deleterious effect on plants after they turn tan in color and reach maturity.

Sprays of 2,4,5-T resulted in death of all halogeton plants treated during the period of susceptibility, while plant kills from 2,4-D averaged about 75 percent. Use of solutions containing mixtures of the two chemicals indicated that a proportion of two-thirds 2,4-D and one-third 2,4,5-T gave more effective kills than 2,4-D alone. The mixture costs less than straight 2,4,5-T and not much more than 2,4-D.

Germination of halogeton seeds ranged from around 25 percent of the original stand after spraying in the early part of the susceptible period to less than 10 percent when spraying was done toward the end of the period. This indicates that any particular area must be sprayed two years and possibly three to eliminate the weed completely.

Simply removing halogeton from an area does not always mean control has been achieved, especially when small areas are treated. Spraying should be followed by reseeding of perennials to prevent the area from being occupied by more halogeton than before. This happened on one plot where all halogeton plants were killed by a 1:1 solution of 2,4-D and 2,4,5-T during 1949. Most other competing vegetation, primarily sagebrush and rabbitbrush, was also killed, and in 1950 halogeton had regained complete domination of the area.

For this reason chemical sprays should be used with caution on halogeton, preferably on critical areas where such treatment can be followed by the reseeding of adapted species.

PROGRAM FOR 1951

Colorado River basin studies

Success or failure of the plantings made in the Colorado River basin during 1950 will be studied during 1951. Additional observations will be made in the important vegetal types and an over-all plan developed for future studies and observations.

Methods of removing competition

The study of chemical methods of brush and weed control will be continued. Special efforts will be made to determine the most economical applications. Mechanical methods and removal of brush by burning will continue to be studied. Removal of pinyon-juniper and subalpine weeds will receive careful consideration.

Methods of revegetation

Studies of the effect of mulches and fertilizers in promoting revegetation of the loose, granitic slopes in southwestern Idaho will be continued. The use of sprayed cheatgrass mulches as a means of helping to revegetate these loose soils will be examined. Rhizome planting for barren dry south slopes and of flood water irrigation for producing forage in dry areas of southern Utah will be followed up. Another set of data on the pellet seeding project at Kigalia will be recorded to supplement data reported in 1949. It is thought that this will complete the observations on the use of soil pellets.

Site factors

The following studies on site factors will be prosecuted with as much vigor as funds and personnel permit:

1. How to revegetate sites in the desert shrub areas.

2. How to restore plant cover on the loose granitic soils of southwestern Idaho.

3. How to evaluate potential forage and cover production of various kinds of soil in different locations in the sagebrush and mountain brush zones.

4. What restoration of plant cover and forage can be obtained in various sites in the subalpine and spruce-fir zones.

5. How to improve salty lowlands with production of high value forages.

Plant breeding

Promising strains of suitable forage species will be added to our collection and their value determined as rapidly as possible. Cooperative relations will be maintained with the nursery section of the SCS, the Western Grass Breeders, and particularly with Dr. Wesley Keller, in charge of grass breeding work at Logan for the BPISAE.

Utilization

Grazing studies at Benmore, Ephraim, and Dubois will be continued in the same design as in 1950. An effort will also be made to ascertain grazing utilization of large-scale seedings made by the Forest Service. It is planned to develop a manuscript from Benmore findings as soon as significant results are available.

Halogeton

Observations will be continued on the spread, growth habits, and control of halogeton. The Station will cooperate with the Regional Office and with other Federal and state agencies in restricting the spread of this poisonous plant. If funds become available, a well-organized investigation of control methods will be started.

RANGE ECONOMICS RESEARCH

The wild lands of the Intermountain West are the principal sources of irrigation and culinary water, hydro-electric power, timber, recreation, and wildlife, and they provide a substantial amount of forage for the domestic livestock of this region. Resource managers must recognize the physical limitations of wild land productivity in the various uses in order to maintain a desirable level of continued production. Cognizance must also be taken of the domestic, agricultural, and industrial needs of the communities in deciding what combination of uses is the optimum from the standpoint of sustained human welfare.

The physical factors affecting resource uses are the subjects of physical science research. The factors affecting resource allocation to various uses are the subjects of economics research. Resource allocation, which is a very important responsibility of the wild land manager, is best accomplished only when both the physical and the economic facts and the limitations of the resource uses are known and applied. Economics research is therefore a necessary complement to other wild land research.

RESOURCE INVENTORY AND ANALYSIS

Resource management requires a knowledge of what the resources are and how they should be used. Although no comprehensive resource inventories have been made in the Intermountain West in recent years, considerable information is available and has been compiled on wild lands and their uses. Facts are available on the extent of present and potential irrigated areas, developed and potential reservoir capacity, water power developments, timber areas, volumes, growth, drain, and commercial production, sawmill numbers and labor employment, areas of various kinds of recreational use and numbers of visitors, the extent of fishing streams and lakes, estimates of game numbers and the annual game harvest, numbers of sportsmen using some wild land areas, acres of cropland and grazing land, extent of the grazing use, livestock inventories, farm and ranch income, land ownership, and total land areas. All this is useful information and its analysis provides interesting comparisons and a better understanding of resource uses, needs, and capabilities.

The Intermountain West may be said to include the eight states: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming. The water produced here was used, according to the 1945 census of agriculture, to irrigate approximately 10,703,000 acres of land within the region and also large areas in Washington and California. The area irrigated constituted less than half of the possible irrigable area estimated by the National Resources Board. Bureau of the Census estimates of waterpower developments show that in December 1945 only about 10 percent of the estimated ultimate waterpower capacity had been installed. Water is an important source of the wealth of these states and its development and management are just beginning.

Estimates made by the U. S. Forest Service show that the total commercial forest area of the eight Intermountain states is 43,701,000 acres, which is somewhat smaller than the commercial forest area of the two states of Oregon and Washington. Of the total timber volume in these forests (47,924,000,000 cubic feet in 1945), approximately 65 percent was in sawtimber sizes. Forest growth is mostly in the less-than-sawtimber sizes. According to the 1945 figures total growth exceeded drain (commodity production, losses by fire, and destruction by insects, disease, and other causes) by 75 percent, or by 315 million cubic feet annually. In the sawtimber sizes, however, total growth is only about 71 percent of the estimated annual drain.

The Intermountain West must import much of its annual wood products needs. Lumber movement figures for 1943, for example, show that almost 43 percent of the lumber was imported, mostly from the Pacific Northwest.

According to Bureau of the Census and the Forest Service, 1,733 sawmills were active in 1947, providing employment in the woods and plants for 18,680 workers. Many additional workers were employed in further processing, in distribution, and in dependent industries.

Recreational use of wild lands is an important consideration in planning management operations. Almost 7 million recreation visits were estimated for the 1949 fiscal year on areas under the jurisdiction of the National Park Service. The national forest recreation areas had an estimated number of visits in excess of 8 million during the calendar year 1949. No satisfactory estimates are available on what this recreation use means in terms of community income, increases in property values, or in the intangible returns to the recreationists themselves.

The national forests of the Intermountain West had an estimated 1,447,000 sportsmen during 1950 who harvested 28,000 elk, 148,000 mule deer, 6,000 other species of deer, 2,000 black bear, and who fished in the 34,400 miles of fishing streams and 270,000 acres of fishing lakes. The resource values in wildlife use remain unestimated.

The contribution of the wild lands to the production of livestock products in terms of money value has not been satisfactorily calculated. Estimates of the Bureau of Agricultural Economics for the year 1949 show that the cash receipts from farm marketings in the eight states were $950,953,000 for livestock and livestock products and $900,573,000 for crops. Domestic livestock is thus the chief source of farmers' income and wild land ranges are important sources of forage to many ranch operations.

This resource inventory and analysis is a current activity of the Division of Range Economics.

VALUES IN MULTIPLE-USE MANAGEMENT

Publicly owned wild lands are best managed under the multiple-use concept. Expenditures are made in resource management activities in a manner calculated to result in the greatest total net return in goods and services to society as a whole. This procedure will usually result in a combination of several wild land uses in a management unit. A change in any one of the uses will affect the total net returns from the multiple use, and a change in the general economic environment will have an impact on the combination of wild land uses. The manager of publicly owned wild lands contemplating an adjustment in any of the uses, or productive activities, must consider (1) all management alternatives to the proposed change, for example, effect of fencing, water development, and reseeding activity before making a livestock grazing use adjustment; (2) the effect of the proposed adjustment toward the objective for which it is made, for example, soil stabilization; (3) the effect of the change on the net income to the community; and (4) the impact of foreseeable general economic changes on the proposed land use adjustment. Better understanding of the relations of land uses to their private and social values will aid resource managers in making decisions in the public interest. Investigation of the values involved in the multiple use of wild lands has been started by this division.

EXTENDING ECONOMICS CONCEPTS

Another important activity in the field of range economics is that of exchanging ideas with other research workers and with wild land technicians. This is accomplished for the most part through discussion of topics of mutual interest, although publications likewise may be used for this purpose. Research and management are benefitted if the useful ideas of economics enter into the thinking, planning, and the execution of the physical science research work or the management of wild lands. The economist will benefit greatly by becoming aware of the latest thought, activity, and accomplishments in other fields. As a result he can modify and develop the theory and practice of the social science with which he is working, as well as promote interest and better working relations among technicians in wild land management.

Economics research can make valuable contributions to the management of wild land resources. Together with the discoveries in other fields of research it can do much toward reaching the goal of conservation: the maintenance of a maximum level of sustained human welfare.

FOREST MANAGEMENT RESEARCH

The most pressing problem of the Intermountain region is how to cut overmature and merchantable second-growth ponderosa pine forests in order to secure natural regeneration and the highest possible net sawtimber growth per acre in southern Idaho where the bulk of this important species is located. During the past year considerable effort has been directed toward designing an experiment which will answer these questions and which can be installed and completed with existing funds and personnel. Plans for this design have been completed and it is proposed to start work on the preliminary layout of the experiment in the spring of 1951.

During the past year it has been possible to analyze data from some old methods-of-cutting studies in overmature ponderosa pine, to make a preliminary tree classification for Douglas-fir, to analyze the effects of rodent feeding, to test the viability of stored seed from different sources, and to study the physical arrangement of certain root systems. These studies and some of the results obtained are discussed below.

METHODS OF CUTTING PINE CREEK PLOTS

The Pine Creek plots, located on the experimental forest near Idaho City, were laid out in 1933 and remeasured in 1938 and 1948. They were cut by different intensities and by different methods but no insect risk markings were included. Volume removed varied from 50 percent to 96 percent. Net growth varied from -208.6 fbm per acre per year for the 5-year period to 55.3 fbm per acre per year for the 15-year period. Insects were responsible for 77 percent by volume of the losses which in some cases reached a total from all causes of 334.4 fbm per acre per year on a 5-year basis to 162.4 fbm per acre per year on a 15-year basis. It is obvious from these figures that, even though no replications are available, the heavy volumes removed on some plots should have reduced insect losses more than they did. Since they failed to do so, one is prompted to believe that insects may be the chief cause of mortality in cut-over overmature ponderosa pine in southern Idaho.

When reproduction of both ponderosa pine and Douglas-fir on these plots is considered, there has been a 4.5 percent decrease where slash was piled and burned compared with a 24.2 percent decrease where slash was untreated. This is puzzling considering the fact that two extra-heavy seed crops have occurred since cutting, one of which was followed by well-distributed, above-normal precipitation.

Details of these plots and of the analysis made have been prepared for publication.

PRELIMINARY DOUGLAS-FIR TREE CLASSIFICATION

From information secured during the remeasurement of the Pine Creek plots, it was possible to formulate a tree classification for Douglas-fir based on vigor and age in cut-over stands.

Vigor is understood to be the total net effect of all factors producing growth, a conception so far unused as a basis for classification of this species. This may serve as a preliminary basis from which marking rules can be designed. A relationship between age and vigor in cut-over stands, checked against virgin stands, is apparent in the classification.

It is planned to publish this study as a Station paper in the near future.

RODENT DAMAGE

During the remeasurement of the Pine Creek plots, information was collected on the feeding by porcupines on saplings and poles. Examinations for rabbit and porcupine feeding were made in some ponderosa pine plantations established on large burns in southern Idaho.

Sapling and pole feeding

Trees examined varied in size from 3.6 inches to 10.9 inches d.b.h. and were collected from randomly selected subplots from the seven 10-acre methods of cutting plots in Pine Creek. The following facts were established:

1. The denser the pole stand the greater the percentage of trees fed on.

2. Feeding increases on trees from 3.0 inches up to 9 inches d.b.h. and then drops off sharply.

3. The dominants are commonly attacked.

4. Of 1,921 trees examined in sapling and pole stands, none was killed as a result of porcupine feeding.

Rabbit and porcupine feeding in plantations

Two ponderosa pine plantations, some 8 miles apart and 13 and 10 years old were examined for injury and mortality. The following facts were established:

1. There were none dead and 21 percent damaged in the first plantation and 1.41 percent dead and 23 percent damaged in the second.

2. The distribution of numbers of trees in each of the classes, undamaged and damaged and girdled, is independent of locality.

3. The chances of occurrence of undamaged or damaged conditions are not equal.

4. The ratio of undamaged to damaged to girdled stems follows an assumed 16:4:1 ratio.

SEED VIABILITY

The infrequency of heavy seed crops in ponderosa pine suggests the desirability of knowing if the seed of trees of certain ages found at different altitudes and stored in different ways can retain their viability. If viability does not deteriorate appreciably and an inexpensive method of storage can be found, then the problem of seed collection and storage for future use becomes less serious. The germination tests made during 1950 provided some interesting clues to these questions. Seed used was collected from the 1936 crop from immature stands ranging in elevation from 4,000 feet to 5,500 feet altitude. Seed lots were stored in air-tight containers under the following conditions: (1) Commercial cold storage at 0°F; (2) commercial cold storage at 32°F; (3) Above-ground insulated storage where temperatures ranged from 30°F to 55°F; (4) below ground in a loose-covered metal container some 30 inches beneath the surface where temperature varied from about 30°F to perhaps 55°F; and (5) in an attic admitting no direct sunlight where temperatures ranged from -40°F to 108°F annually.

While final results will have to await statistical analysis in order to establish the significance of slight differences, the following trends are evident:

1. If ages and altitudes of parent trees are ignored, commercial cold storage at 32°F possessed the highest germinative capacity (69.8 percent), followed by commercial cold storage at 0°F (65.5 percent), cellar storage (55.6 percent), underground storage (50.0 percent), and attic storage (0 percent).

2. If storage methods are ignored, seed from young normal stands at 4,000 feet elevation possessed the highest germinative capacity (64.4 percent). Scattered old growth at 5,500 feet altitude possessed the lowest (51.6 percent).

3. The germination period extended from July 5 to October 18.

ROOT STUDIES

The effects of competition in reducing available moisture for tree growth is an important consideration in southern Idaho. The more that is known about the root systems of trees and competing vegetation, the better can the silviculturist visualize obstacles to growth of both seedlings and mature trees.

Since a means of hydraulic excavation was available at the Boise Basin Branch Station, the root sections of a 17-inch diameter breast high ponderosa pine and a typical, open-growing Ceanothus velutinus were exposed for study. Although the data are in preliminary form, some interesting and useful facts are apparent.

Ponderosa pine

1. Deepest root penetration was in the vicinity of the tree base.

2. Lateral roots extended some 50 feet from the tree base.

3. For the most part, laterals were 12 inches or less from the ground surface.

4. Small rootlets grew from the tree base.

5. Competition for rootlets growing on laterals comes, not from other adjacent trees but from roots of lesser vegetation on the forest floor.

6. The roots of a tree evidently are not evenly distributed in the four quadrants encompassing it. Therefore, unless trees are closer together than adjacent trees were in this study, competition between tree roots is not necessarily present.

7. Where soil formation tends to be compact, rootlets will follow fractures and cleavage planes.

Ceanothus velutinus

1. A ring count of the stem is no indication of the age of the root system which evidently can survive fire.

2. Roots penetrated to a depth of at least 50 inches.

3. Rootlets from main roots of the plant were not abundant.

4. The root stem just below the ground surface was 4 to 5 inches in diameter.

5. Roots extend laterally further than the crown perimeter.

PROGRAM FOR 1951

A start will be made on the installation of the methods-of-cutting study in virgin ponderosa pine designed to evaluate the effects of two methods of logging, two methods of marking for high and low volume reserves in each of three condition classes based on different initial volumes per acre. Considerable preparatory work must be completed before the actual cruising, marking, and plot establishment can be carried out in 1952.

Presentation of work accomplished in 1949 and analysis of incidental studies finished in 1950 will be brought up to date after records on the methods-of-cutting study have been completed.

FLOOD CONTROL SURVEYS

During 1950 flood control survey activities of the Station were largely devoted to the revision of reports on surveys conducted in previous year and participation in the comprehensive agricultural survey of the Columbia River basin. A number of revisions and changes were necessary in the Boise, Sevier, Fountain Creek, and Wasatch Front reports, all of which were in various stages of review and completion. For the most part, the revisions were brought about by the necessity for bringing the survey reports into conformity with Departmental principles and procedural policies which were announced during the year.

Flood control survey work on the southern Idaho portion of the Columbia River basin is an integral part of the over-all survey of the basin, and was geared to survey activities at the other stations concerned in the basin. It was also necessary to coordinate our work with that of the Field Committee and other agencies of the Department of Agriculture participating in the preparation of the Comprehensive Agricultural Program.

A considerable amount of time was devoted to completion of the Virgin River survey. However, total time spent on this survey represented a considerably smaller portion of the facilities of the division than was allocated to the two major work objectives.

COLUMBIA RIVER BASIN

An important phase of the work on the Columbia Basin was that of the flood control survey field committee in developing a basin-wide flood control survey work outline, and the coordination of this outline with the over-all plans of the USDA Field Committee. This involved numerous meetings of the flood control survey field committee made up of the Division Chiefs from the California, Pacific Northwest, Northern Rocky Mountain, and Intermountain Stations, and a representative of the Soil Conservation Service. Members of the division served on technical subcommittees assigned to land use, hydrology, engineering, and economic phases of the flood control survey in the development of sectional working flood control survey in the development of sectional working plans, technical standards, uniform nomenclature, and procedures. Most of this work was completed by midyear.

With the exception of snow investigations, field work could not be conducted until about mid-June. Nevertheless, available time was well used in the collection, revision, and analysis of data from secondary sources including that pertaining to soils, geology, cover types, and status of aerial photographs. This phase of the job also included the calculation and preparation of drainage area tables, compilation of stream flow and precipitation data, the review of aerial photography, and the procurement of needed aerial photographs and mosaics. In addition to the assembling of other basic data, base maps of the work area of this Station and the five principal hydrologic subdivisions were compiled and reproduced.

Snow observations, Snake River, 1950

During the winter, spring, and early summer of 1950, the effect of forested and open areas on interception and melting of snow was studied on 17 pairs of plots, and in addition the effect of slope, elevation, and exposure on melting rate of snow was observed at 27 snow courses located in the open. These study plots and snow courses ranged in elevation from 4,000 to 9,600 feet and were located on the Boise, Payette, Targhee, and Teton National Forests. Although monthly surveys were made during the snow storage and melt periods, during spring melt some measurements were made at weekly intervals.

Interception of snow by forests at the start of spring melting varied widely according to the type of cover. It ranged from less than an inch to over 14 inches of water equivalent. Closed sapling stands (three plots) averaged 1.0 inch less water equivalent than adjacent openings, closed pole stands (three plots) averaged 4.0 inches less, open mature stands (seven plots) averaged 7.0 inches less, and closed mature stands (four plots) averaged 14.0 inches less. Most of the sapling and pole stands were of lodgepole pine, while the mature stands were in ponderosa pine, Douglas-fir, alpine fir, and Engelmann spruce.

The melting rate of snow in the forest averaged about 70 percent of that in the open. Melting rates in the forest varied from 0.2 to 1.0 inch of water daily. Snow melted on large level openings at rates from 0.5 to 1.5 inches daily. Small clearings shaded by trees varied in melting rate from 0.4 to 1.2 inches daily.

Snow melting rates between weekly or monthly observations when compared with average temperature at valley stations indicated a relationship of about 0.05 inch of melting per degree above freezing. These snow interception and daily melt rates compared favorably with preliminary results obtained from about 70 similar studies conducted by the Northern Rocky Mountain Station in northern Idaho and western Montana.

Soil moisture samples were taken at snow study plots under forest and in the open to observe soil storage and losses from melting snow. Occasional samples were taken from March to June and a total of 80 samples at all snow plots were taken in September 1950. In the fall, only part of the samples showed a difference in soil moisture between forest and open conditions. This difference averaged 4 percent more water in the open for the top 2 or 3 feet of soil.

During the summer a timber cruise of about 20 forested snow plots was made. The timber types, size, height, age, growth rates, and canopy density were obtained. Other plot characteristics were also recorded including topography, soils, and erosion. The total volume of timber (including nonmerchantable) appears to be related to snow melt rates and the crown density correlates with interception losses.

Cover and condition studies

A reconnaissance inspection of some 70 potential sample areas was made early in the field season. Most of the potential samples consisted of small gaged watersheds selected in advance as possible samples for land condition-hydrologic investigations. Following this reconnaissance some 60 areas were selected for later study of which 50, of comparatively small sizes, have stream flow gage information of sufficient duration to warrant their use in hydrologic analysis. During the remainder of the field season 22 of these sample watersheds, ranging in size from 6 to 200 square miles, were surveyed in considerable detail to obtain information on plant cover, soils, watershed condition, and preliminary information on improvement measures.

These studies, largely confined to forested watersheds, include the collection and recording of information on stand composition, age, total density, total timber volume, merchantable volume, increment rate, and soil classification including depth, texture, and erosion conditions. For the larger size sample watersheds the above data were taken on one-fourth acre plots selected at random in the major timber types. On two of the sample watersheds, involving some 300 square miles, work included timber type mapping by delineation on aerial photographs.

On a few of the gaged sample watersheds it was necessary to establish a network of vertical controls since topographic maps were not available for these particular areas. Although the season's accomplishment in the study of the sample areas leaves a considerable number of samples to be studied, the work was completed on most of the high elevation forested watersheds and those of larger size.

All the snow plot data and timber surveys will be used to determine the snow runoff characteristics of forested watersheds for correlation with long-time stream gaging records. The effects of land management should appear in such a study to provide a basis for predicting program effects.

Project work inventory

The flood control survey assignment of the Station in connection with the comprehensive survey of the Columbia will require a great deal of reliance on the results of the revision of the Project Work Inventory now being conducted by the Forest Service, and a considerable amount of time was spent by members of the survey staff in assisting Region 4 in preparation of standards and the formulation of procedures to be observed in carrying out this reinventory. Activities in connection with the Columbia River basin are summarized in table 18.

Table 18. Summary of Columbia River basin survey activities, December 1950

Job	Field time	Office time	Total
		(Man-months)	
Hydrology (2 men)			
Reconnaissance	1	2	3
Snow surveys	5	3	8
Gaged watersheds	1	3	4
Sediment surveys	½	½	1
Meetings	½	1½	2
Subtotal	8	10	18
Land Use (5 men)			
Reconnaissance	1½	2	3½
Timber surveys	3	1	4
Range surveys	1½	1	2½
Timbered snow plots	1	1	2
Meetings	1	3	4
Subtotal	8	8	16
Economics (2 men)			
Reconnaissance	¼	-	¼
Damage appraisal	¼	1	1¼
Meetings	½	1	1½
Subtotal	1	2	3
Engineering (1 man)			
Reconnaissance	1/8	-	1/8
Drainage areas	-	1	1
PWI standards	-	1	1
Meetings	-	1	1
Subtotal	1/8	3	3-1/8
Drafting (2 men)			
Base maps	-	5	5

BOISE RIVER

Revision of the Boise River flood control survey report required staff review and was completed early in the year. This involved a detail to the Washington Office of one of our staff members during April for a period of approximately 2 weeks. The report was forwarded to the office of the Secretary of Agriculture in August, and following review by that office and other bureaus of the Department, was returned to the Forest Service in November for further revision on several important points, especially those pertaining to the evaluation of damages and benefits. The questions raised by these comments were of such significance that they required a careful study, not only by this Station, but the Washington Office as well. Another detail to Washington by the

Division Chief for a period of approximately 3 weeks was necessary. Forest Service replies to the comments received were submitted to the Secretary's office in late December, and at the close of the year no final conclusion had yet been reached concerning the final form of the report.

The principal problems involved are common to many other river basins of the West. The joint effort to arrive at a fully acceptable procedure therefore appears to be of a great deal of importance in clearing the way for the preparation, compilation, and clearance of reports not only for this particular basin but for others.

Field concurrence in the current draft of the report was obtained from the Idaho Agriculture Extension Service and the Idaho State PMA Committee. While not presented for official review, the report was also discussed in considerable detail with the Idaho State Fish and Game Commission, the Idaho State Engineer, and the Idaho Reclamation Association.

SEVIER LAKE

Revision of the Sevier Lake survey report as required by the comments of the Washington Office of the Forest Service and other bureaus of the Department of Agriculture was completed during the forepart of the year. The report was also reviewed by the office of the Secretary of Agriculture, approved by him, and submitted in May to the Governor of the State of Utah and to the other members of the Federal Inter-Agency River Basin Committee. Comments by the Department of Interior received by the Secretary of Agriculture in November prompted a meeting of representatives of the Department of Agriculture and the Department of the Interior to discuss the comments of the latter agency. From this discussion it appeared that most of the questions raised could be satisfactorily answered by minor revisions. However, it was decided that the processing of such revisions would be postponed until the Department had received comments from the other FIARBC agencies, especially the Corps of Engineers.

At the request of Watershed Management in Region 4, a member of the survey staff participated in a meeting of the national forest supervisors represented in the Sevier Lake Watershed to consider ways and means of correlating work plans and other needed activities among the several Federal and State agencies involved in the watershed, providing the report is approved. A similar meeting, also attended by a representative of the division, was held with representatives of the Utah State Engineer's office, Utah State Fish and Game Commission, the Production and Marketing Administration, Bureau of Land Management, the Fish and Wildlife Service, and the special representative of the Secretary of Agriculture for the Colorado River and Great Salt Lake basins. Representatives of the Soil Conservation Service were unable to attend. Flood control survey work on this watershed will be of direct concern to all of these agencies and these exploratory meetings were profitable in laying the ground work for much of the work which will need to be done if the report is approved by Congress.

WASATCH FRONT

A preliminary typewritten draft of the survey report of the Wasatch Front was completed early in the year and was reviewed by the Washington Office of the Forest Service and the regional offices of the SCS. Following these reviews a number of revisions were required. These were completed late in the year.

Although the first draft of the report was not formally submitted to the field offices of the FIARBC agencies, it was submitted to and reviewed by local representatives of the Bureau of Reclamation engaged in preparing project plans for the Weber Project. At their suggestion several changes which concern improvements contemplated as part of the Weber Project were made in the latest draft of the report.

FOUNTAIN RIVER

Numerous changes were required in the Fountain River report to adapt it to the procedures established by the Department during 1950. Meetings with the Colorado State PMA Committee and the Extension Service were held to facilitate the collection of data on going programs. Similar information on the going program was obtained from the SCS. Newly established procedures for the separate evaluation of group 1 and 2 measures required considerable revision of the recommended program.

Other changes were made as a result of comments by the Division of Forest Influences, the regional office of the SCS, Colorado State PMA, Region 2 of the Forest Service, and the Rocky Mountain Experiment Station. The resulting revised report was completed and forwarded to Washington in early July. At the same time copies were again circulated to the other offices listed above and to the Colorado Extension Service. Concurrence from the SCS was obtained together with suggested minor changes in language. Concurrence was also obtained from the Colorado PMA, Region 2 of the Forest Service, and the Rocky Mountain Experiment Station but no reply has yet been received from the Extension Service.

Copies of the report were also reviewed by the representatives of the Bureau of Agricultural Economics at Lincoln, Nebraska, and Berkeley, California, who raised a number of questions and suggested some revision. A copy of the report was also presented to the Colorado Water Conservation Board for informal review.

The report was returned to the Station by our Washington Office in November, together with suggestions for final revision and reprocessing.

At the close of the year the second revision was practically completed but reproduction of the report was postponed pending the outcome of discussions with the office of the Secretary regarding some portions of the Boise report which also affected the Fountain report.

VIRGIN RIVER

All field work was completed during the forepart of the year. This included field meetings with the district offices of the BLM, Indian Service, and national forests to obtain information on going programs and the additional program to be recommended. A public meeting, called by the Nevada Extension Service was also held at Las Vegas, Nevada, in March to discuss flood control needs and the proposed program with local interests and local representatives of Federal and State agencies. Separate meetings were held with the Utah State Fish and Game Commission and the Fish and Wildlife Service to reach accord on the fish and wildlife problems, needed corrective measures, and the effects of the over-all program upon fish and wildlife. Correspondence was begun with the Fish and Game Commissions of Arizona and Nevada for similar purposes.

The division of Range Management Research assisted the flood control survey group in an insepction of range improvement results on the SCS range management demonstration areas at Panaca and Crystal Springs, Nevada. These areas, under controlled management since about 1938, are important since we have a very limited basis by which to measure the beneficial effects to be expected from range management or other range improvement measures in the semidesert types which comprise many thousands of square miles in this watershed.

A member of the survey staff also accompanied representatives of the BLM and the division of Forest Influences in an inspection of blackbrush areas on BLM lands which have been burned, both accidentally and intentionally. The conclusions have been considered in preparing the flood control survey report since extensive areas of this shrub type occur on the watershed.

During the year it was learned that the Dixie Project proposed by the Bureau of Reclamation had not been authorized, and that early Congressional approval of this report was doubtful. This made necessary considerable revision of the preliminary draft of the report especially with respect to hydrologic analysis, sedimentation damages, and the anticipated benefits from sediment control.

At the close of the year a first draft of the report had been completed and the appendix material was about 85 percent complete.

UPPER ARKANSAS RIVER

In October the Forest Service agreed to begin the survey of the Upper Arkansas River (above Pueblo, Colorado) in order to obtain flood control information and recommendations on the area for inclusion in the Arkansas-Red-White comprehensive survey and report. Because of the lateness of the season no field work could be done and the survey staff was fully occupied on other tasks of equal priority. As a result relatively little was accomplished on this watershed, although it was possible to assemble and review some of the basic data available from secondary sources. A survey work outline was completed in draft form and preliminary discussions were held with the SCS regarding assistance by that agency on the agricultural lands.

OTHER ACTIVITIES

Assistance to the Soil Conservation Service.--Assistance to the SCS on surveys for which that agency is responsible through their Albuquerque office required about 16 man-weeks of field and office time during the year. Included in the several tasks involved was the completion of flood control investigations on the forest and woodland portions of the Upper Arkansas Watershed (below Pueblo). This was followed by the preparation of a program of recommended measures for such lands which was submitted to the SCS in November, together with a report on the conditions and problems disclosed by the survey, and an analysis of the benefits anticipated following program installations.

Another major part of these activities was that of revising Forest Service flood control recommendations for the national forest lands in the Middle Rio Grande Watershed in accordance with procedural directives announced by the Secretary of Agriculture late in 1949 and supplemented in 1950.

A lesser amount of time was devoted to review of recent revisions of flood control survey reports on the Queen Creek and Pecos River Watersheds.

The division also assisted the SCS in a resurvey of the Salt Creek-Wahoo Watershed in the eastern central part of Nebraska. Forestry problems studied were chiefly those relating to farm woodlands and tree and shrub plantings for the stabilization of severely eroded areas. Wendell Harmon, recently farm forester in eastern Nebraska, was loaned to the survey staff by Region 2 for this short assignment. Working with Brandeberry, the Forest Service representative on the Missouri River Basin Agricultural Field Committee, Harmon examined existing farm woodlands, lands to be retired from cultivation to permanent cover, and severely eroded areas in need of erosion control plantings. After the necessary field work a report was submitted to the SCS which briefly depicted current condition of the woodlands, and proposed a program including cost of improved management of existing woodlands, conversion of cultivated lands to woodlands, and erosion control plantings. This Forest Service report also included an evaluation of anticipated benefits which would be provided by the recommended forestry measures.

Advance studies

Colorado River basin.--Preparation of a flood control problem analysis of the Colorado River basin was begun in January. When completed it will include background material and generalized summaries on area involved, land ownership, land use, plant cover, economy, present watershed conditions, and past and current investigations as they pertain to flood control. This analysis should also indicate, in a broad manner, the additional research studies needed in the basin to solve the principal flood and sediment control problems.

Most of the basic background material has been collected and analyzed and a rough draft copy of most of the analysis prepared. Reports on the current investigative program have not yet been received from all stations and higher priority assignments have resulted in postponement of completion date.

Lobenstein was detailed to Washington for approximately 5 weeks in March and April to assist in preparing the Forest Service report on the Colorado River basin for use by the President's Water Resources Policy Commission. Subsequent to this assignment additional time was spent by members of the division in assembling additional data and reviewing preliminary drafts of material related to the work of the commission.

During early summer Carlson accompanied representatives of the divisions of Range and Forest Influences Research and of the BLM on several trips through the eastern Utah portion of the Colorado Basin. These were principally a reconnaissance of possible sites for infiltration tests, reseeding pilot studies, and a preliminary inspection of BLM range enclosures which might be used to supplement present knowledge of range recovery potential.

The division took part in a reconnaissance survey of erosion conditions in the San Rafael Watershed in eastern Utah. Others participating in this study were the division of Forest Influences and the SCS flood control survey unit. The San Rafael Watershed was selected as a sample of eastern Utah, western Colorado, and northern New Mexico tributaries which now contribute a large percent of the sediment entering the Colorado River. Objectives were to obtain further information concerning: (1) the source of sediment by major zones and vegetative types; (2) the possibility of future and more detailed investigations which would provide better guides for separating accelerated or induced erosion from normal erosion; and (3) methods of segregating erosion in desert and semidesert areas into sheet, gully, and channel cutting.

This reconnaissance was supplemented in August by a more detailed field study by Adams and Croft. Using pack train for access to remote portions of the watershed, several weeks were devoted to measurements of channels, headcuts, sheet erosion, and observational analysis of the degree and extent of accelerated erosion as compared to normal geologic erosion. Results of these studies will be reported early next year.

Throughout the year members of the division also assisted the Station Director and others of the Station staff in assembling and analyzing data and information needed in connection with the work of the Subcommittee on Sedimentation of the PSFIATC.

Miscellaneous activities.--The division assisted Region 2 and Brandeberry of the Missouri River Basin USDA Field Committee in developing material for use in connection with proposed Congressional hearings on the Missouri River Basin Comprehensive Agricultural Program. This included the preparation of detailed plans for needed improvement measures on three sample watersheds in eastern Colorado. A total of about three man-weeks were required. Later in the year, at Brandeberry's request, we provided information on the classification of forest, woodland, and forest range which was followed in our survey of the South Platte, North Platte, and Laramie Watersheds, and the Black Hills area. In addition, we also furnished information developed during the South Platte survey on the hydrologic effects anticipated to result from the installation of the recommended flood control program.

During the period August 20 to 28 Adams was assigned to the special study on the Roosevelt National Forest to assist in developing suggestions for a structural program for the special study area on the Elk Ridge allotment. A report of his findings and recommendations was completed and submitted to the supervisor of this study.

European foresters visiting the United States under the ECA program spent a part of their time at this Station meeting and talking with members of the Flood Control Survey division on flood and sediment problems, flood control objectives, and survey procedures.

In the late fall a reconnaissance survey was made of the Arrowrock Reservoir in the Boise Watershed. The opportunity to study sediment deposits which was afforded by draining of the reservoir was utilized chiefly to obtain better information concerning the relative extent of removal of sediment deposits from the reservoir by sluicing operations. According to a sediment survey of this reservoir in 1947 by the Bureau of Reclamation made while the reservoir was full, there were about 7,700 acre feet of sediment in the reservoir at that time. Our observations and measurements in 1950 verify conclusions of the Bureau of Reclamation in 1948. It appears that sluicing in 1950, which had not been done since 1942, removed between 400 to 600 acre feet of sediment.

During the latter part of November two members of the survey staff and representatives of Region 4 conducted a special survey of the severe flood which occurred on the Truckee and Carson Rivers in Nevada and California. These investigations were chiefly devoted to study of the sources of flood water runoff, causes of flood discharges, the condition of watershed lands, and possible remedial measures. Following field investigations a brief report was prepared and distributed to the Forest Service offices concerned.

As a member of the Southwestern and Intermountain Subcommittee of the Soil-Site Evaluation Committee of the Soil Science Society of America, Olson assisted in the preparation of a review of literature on soil-site evaluations for forest lands in the Intermountain area. The material covered concerned methods of evaluation and classification of forest lands in relation to tree growth, and features of hydrological significance. The findings were submitted as a contribution to a preliminary report by the Soil-Site Evaluation Committee presented at the annual meeting of the Soil Science Society of America.

PROGRAM FOR 1951

Three major tasks face the division during 1951 and because of commitments on completion dates they must be given priority over all other tasks. They consist of the following:

1. Complete all remaining field work on the flood control phases of the Columbia Basin Comprehensive Agricultural Program. While field work will receive first priority much will also need to be done in analysis of data and in preparing preliminary drafts of various portions of our part of the report. The goal will be to start final analysis of data and writing in January 1952.

2. Complete all necessary revisions and reproduction of the Boise, Sevier Lake, Fountain, and Wasatch survey reports.

3. Complete a flood control survey of that portion of the Upper Arkansas River above Pueblo, Colorado. In order to meet dates established by the AWR Field Committee, this assignment should be finished by late summer or early fall. Survey findings will be submitted to the Forest Service AWR representative for use in preparing the comprehensive AWR basin report.

Another task ahead which is of slightly lower priority is that of completing the field draft of the Virgin River survey report and any revision which may result from its review by field offices of the FIARBC, the Washington Office of the Forest Service, and other bureaus of the Department of Agriculture.

If time permits we will also complete the flood control problem analysis of the Colorado River basin and publish articles on the hydrology of mountain lands which are now in preliminary form.

WATERSHED MANAGEMENT AND PROTECTION

The efforts of this division during the past year were directed mainly toward studies of the kind of plant and soil conditions required for controlling summer storm runoff and preventing accelerated erosion. Progress was also made on studies of watershed improvement measures and consumptive use of water by vegetation. Phases of all three of these watershed management problems were investigated at each of the Boise, Wasatch, and Great Basin Research Centers. In addition, the Wasatch and Great Basin staff carried out some reconnaissance and exploratory studies of the erosion problem in the San Rafael Watershed of the Colorado River basin.

Efforts on the watershed protection requirements problem were devoted principally to the analysis of field data from previous years' work. New field work included a series of infiltrometer measurements in the San Rafael Basin and an examination of numerous watersheds for potential study sites at the Boise Research Center.

A report was completed for publication on the site characteristics that affect summer storm runoff and erosion on undisturbed granitic soil, wheatgrass and cheatgrass range, based on infiltrometer tests near Boise. Additional infiltrometer data from tests on disturbed wheatgrass and cheatgrass range were analyzed and a progress report developed on the status of the infiltrometer approach to the determination of watershed protection requirements. In addition, a detailed problem analysis for a comprehensive program of influences research in the entire Boise province was developed.

At the Wasatch Center, a detailed analysis was made of some 14 years of record from the Parrish runoff plots. The findings from this study were developed into a rough draft for publication.

At the Great Basin Center, effort was concentrated on the analysis of 35 years of records from the A and B watersheds. The large volume of data has made this a difficult and time-consuming job. By the end of the year, however, the analysis had nearly been completed.

Effort on the problem of developing effective watershed improvement measures included the initiation of one new study at the Boise Center and continuation of observations on the effects of contour trenching at the Wasatch Center. The new study on the Boise was developed in cooperation with the division of Range Reseeding. It is directed toward finding ways of revegetating depleted and eroding range lands having a coarse granitic soil, the extent to which soil moisture is a restricting factor, and whether mulching and different types of plants can cope with this limiting factor. Representatives of the Station assisted the Manti National Forest in designing and installing contour trenches and reseeding a portion of the flood-source areas of the Mt. Pleasant Watershed.

Studies of consumptive water losses were devoted mainly to the analysis of accumulated data, though some supplemental field work was also done. In order to complete the analysis of data pertaining to moisture on reseeded and depleted ranges in the Boise area, it was necessary to obtain additional soil samples from the test areas and to make determinations of field capacity and wilting point values. The laboratory work was done at the Utah State Agricultural College. Analysis of these data was completed and a tentative draft of a report on the study was developed. At the Wasatch Center, a report was developed covering the evapo-transpiration losses that occurred over a 3-year period on aspen, herbaceous, and bared sites. In addition, detailed calibration tests of the Coleman moisture meter were made as a basis for the installation of this equipment in an extension of the evapo-transpiration study. At the Great Basin, stream flow records were continued on two range watersheds intended to test the effects of intensive improvement measures on water yield.

WATERSHED PROTECTION REQUIREMENTS

Recent infiltrometer tests together with extended records from permanent runoff plots and entire watersheds have revealed much useful information on the effects of plant cover and soil conditions on the control of summer storm runoff and erosion. The results of these investigations in some instances are sufficiently conclusive to warrant the adoption of at least tentative goals for watershed management. The highlights of findings in three of the recognized problem areas of the region follow:

Granitic soil-grass range

The upper drainage basins of the Boise, Payette, and Salmon Rivers in southern Idaho present an especially difficult watershed management problem. These drainages are characterized by a coarse-textured, loose-grained, granitic soil with little cohesiveness; by high-intensity summer rainstorms; and by steeply sloping topography. Under such conditions the soil is highly susceptible to erosion from raindrops and surface runoff and to displacement by livestock trampling and logging.

Sediment load measurements from numerous subdrainages, representative of forest as well as range cover conditions, have shown that the lower mountain and foothill lands are major sources of sediment to downstream irrigation structures and lower valley stream channels. Erosion source surveys as well as direct observations of gullying and sediment deposition have made it apparent that the most serious sediment-source areas are the steep south-facing slopes on the spring-fall range. Much of the soil on this kind of range has been exposed directly to the influence of rain and runoff as a result of plant cover destruction, chiefly by overgrazing and fire.

Research at the Boise Research Center during the past few years has been focused on determining the kind of plant and soil conditions necessary to control storm runoff and erosion under the impact of torrential rains on wheatgrass and cheatgrass range. Eight site characteristics included: (1) ground cover (percent of ground covered by basal area of plants and litter); (2) area covered by plant crowns;

(3) size of bare soil openings between plants and litter patches; (4) amount of erosion pavement; (5) capillary soil pore space; (6) non-capillary soil pore space; (7) soil depth; and (8) land slope.

The amount of ground cover and the size of bare soil openings were found to be the most influential of the eight site characteristics tested for controlling runoff and erosion. Ground cover primarily affects runoff, and size of bare openings affects soil erosion.

Additional tests were made to determine the effects of of heavy trampling. Where 60 percent of the ground surface was disturbed--comparable to the disturbance caused by heavy grazing--the amounts of runoff and erosion were appreciably increased (table 19).

Table 19. Runoff and erosion during applications of 1.80 inches of rainfall in 30 minutes on 6 x 6-foot infiltrometer plots before and after ground cover disturbance by trampling on some granitic soil range lands

Before disturbance				After 60 percent disturbance			
Minimum ground cover	Maximum bare soil opening diameter	Surface runoff	Soil erosion	Minimum ground cover	Maximum bare soil opening diameter	Surface runoff	Soil erosion
Percent	Inches	Percent	Lbs./A.	Percent	Inches	Percent	Lbs./A.
			Wheatgrass Range				
30	25	19.5	2,072	26	37	21.0	2,700
50	11	13.1	1,147	45	17	15.3	1,620
70	4	7.3	460	63	7	10.1	815
90	4	7.2	455	82	7	10.0	800
90	[1]2	4.0	160	82	4	7.3	460
			Cheatgrass Range				
30	13	17.8	1,375	18	29	32.0	2,525
50	8	8.2	965	33	19	17.5	1,760
70	[2]2	3.3	265	56	7	6.8	520
90	2	3.2	260	85	7	6.5	510
90	[3]1	2.0	140	85	2	3.3	263

Except for the following, the bare opening diameters are the maximum found on the range occurring with the indicated ground cover in 100 percent of cases:

[1] Largest diameter in 96 percent of cases.
[2] Largest diameter in 94 percent of cases.
[3] Largest diameter in 97 percent of cases.

The tabulated values show, in all cases, that the smallest amounts of runoff and erosion occur with the highest ground cover and the smallest bare soil openings. They show also that under undisturbed conditions, both on wheatgrass and cheatgrass range, amounts of runoff and erosion decrease rapidly with increase in ground cover and corresponding decrease in bare opening diameter until beyond a ground cover of 70 percent no material reductions occur. The requirements for preventing accelerated runoff and erosion on undisturbed sites therefore appear to be a ground cover of not less than 70 percent with bare opening diameters of no more than 4 inches on wheatgrass range, and a ground cover of not less than 70 percent with bare opening diameters of no more than 2 inches on cheatgrass range. Under these conditions, runoff should not exceed 7.3 percent from wheatgrass range or 3.3 percent from cheatgrass range, and erosion losses should not exceed 460 and 265 pounds per acre, respectively, during major storms.

For those whose concept of plant cover is based upon range-survey standards, it is necessary to consider these ground cover values in terms of plant density. A 70 percent ground cover, as the term is used here, includes litter as well as living plants, and is approximately the same as a 35 to 45 percent density by range-survey standards.

Under disturbed conditions, runoff and erosion exceed the amounts from undisturbed range except where ground cover prior to disturbance is at least 90 percent on both cover types and bare opening diameters are no more than 2 inches on wheatgrass range and no more than 1 inch on cheatgrass range.

The extent to which ground cover of as much as 70 percent can be achieved on some of these south-facing range lands is problematical because of inherently poor growing conditions. On sites where this ideal cannot be accomplished, lesser amounts of ground cover should be dispersed uniformly to create the smallest possible bare soil openings between plants and litter patches.

It is even more problematical whether ground cover meeting the requirements for protection of very heavily trampled range, that is, ground cover of as much as 90 percent, can be attained over more than a small portion of the range. It, therefore, appears highly improbable that effective watershed protection can ever be achieved under such intensive disturbance. Further tests on local sites are needed to determine whether, with less than 60 percent disturbance, somewhat less stringent cover requirements will afford effective protection. Similar investigations leading to the development of protection requirements are also needed on other granitic soil cover types.

Aspen-herbaceous range

The mixed aspen and herbaceous summer range is another important problem area in the Intermountain region. Much of this range lies on the steep slopes of the high mountains and plateaus that extend throughout the length of Utah. In recent times summer floods and mud-rock flows of violent force have emanated from many of these watersheds. Destruction has been inflicted on rich farm lands, transportation arteries, and many communities. Stream channels down which these discharges plunged have been greatly enlarged and frequently ripped to bedrock. The ripped channels and tributary gullies have been traced directly to seriously overgrazed and depleted sites in the aspen-herbaceous range as the principal flood-source areas. These depleted sites are not usually extensive, and often make up only a small percentage of an entire watershed.

Storm flow runoff from these flood-source areas generally originates as a result of high-intensity rains with rates in excess of soil infiltration capacities. These rainstorms are usually of small volume but with the bulk of the rainfall concentrated in a short period of time and over small areas of a few square miles or less.

Summer rainstorm characteristics as well as the runoff and erosion behavior of the aspen-herbaceous range have been under study for several years on the Wasatch experimental watersheds in northern Utah. Fifteen years of summer rainfall records from a network of intensity rain gages in that area indicate the frequency of recurrence for maximum 5-minute rainfall intensities to be:

Rainfall intensity Inches/hr.	Recurrence interval Years
1.5	1
1.5 to 3.0	2
over 3.0	4 to 5

Maximum 5-minute intensities of as much as 8.4 inches per hour have been recorded but how frequently these recur is not known. Even storms of 1.5 to 3.0 inches per hour for periods of 5 minutes or more may be sufficient to set dangerous quantities of water in rapid motion over steep slopes. Particularly is this so if the center of maximum intensity happens to be located over depleted flood-source sites.

The tremendous carrying power of concentrated amounts of water rushing down steep slopes and channel gradients is well known to those who have witnessed the trees, logs, huge boulders, and mass of other debris deposited within a matter of minutes by a summer flood or mudflow. Even on the flood-source areas where storm flow originates, the soil detaching and transporting power of water moving over the surface is often great enough to erode large quantities of soil.

Storm runoff and erosion originating on permanent runoff plots representative of both depleted flood-source and of well-covered nonflood-source conditions in the aspen-herbaceous range have been measured since 1936. These records show that the amount of eroded soil increases with increase in runoff, but at a faster rate, as follows:

Storm runoff Percent	Soil eroded Lbs./A.[1]
2.5	32
5.0	80
10.0	360
20.0	1,840
30.0	4,560
40.0	7,360

[1] Estimated wet weight at 80 pounds per cubic foot.

As the tabulation shows, doubling of storm runoff from 2.5 to 5.0 percent increased soil erosion about 2½ times. Doubling of runoff from 5.0 percent caused an increase in soil erosion of 4½ times. Still further increases in runoff resulted in still greater rates of soil erosion.

The aspen-herbaceous runoff plot records also show that runoff is highly dependent not only upon storm intensity but upon the amount of ground cover (table 20). Relatively small amounts of ground cover control runoff during low intensity storms but a total of 65 percent or more of the ground must be covered with plants and litter if runoff in excess of 5 percent is to be prevented during high-intensity storms. It is interesting to note that this is approximately the same amount of ground cover required for controlling runoff from summer storms of comparable intensity on local sites of the spring-fall range in Idaho.

Table 20. Percent of summer rainstorm runoff under different ground cover and rainfall intensities on herbaceous-aspen runoff plots, Wasatch Experimental Watersheds

Total ground cover	Maximum 5-minute storm intensity class		
	Less than 1.5 inches per hour	1.5 to 3.0 inches per hour	More than 3.0 inches per hour
Percent			
0	19	30	45
5	4	24	36
15	2	17	31
25	2	11	24
35	1.5	7	17
45	0	5	12
55	0	3	8
65	0	2	5
75	0	0	3

Records from the runoff plots show further that restoration of depleted sites to ground cover conditions capable of controlling torrential summer rainstorms can be attained by either natural or artificial means. In 1936, depleted herbaceous plots adjacent to aspen stands yielded as much as 47 percent runoff and 320 cubic feet of eroded soil per acre during a single storm. Within 10 years, natural encroachment by aspen and perennial herbs on some of the plots had improved ground cover conditions sufficiently to reduce storm runoff to about 6 percent and virtually to stop soil erosion. On some of the other plots too far removed from aspen stands to be invaded by sprouting, revegetation was slow and runoff and erosion rates remained high. These plots were seeded and mulched in 1947. Since then, storm runoff has been generally less than 5 percent and no soil losses have occurred.

Supplemental structures such as contour trenches may be necessary to aid in restoring very seriously depleted and eroding sites to a condition capable of preventing excessive summer storm runoff and erosion. This type of treatment was applied on seriously depleted portions of several of the Wasatch experimental watersheds during the years 1934 to 1936. No floods have issued from these intensively treated drainage basins since this treatment was applied through these areas have been subjected to several torrential rains that caused floods from untreated but otherwise comparable watersheds. A dense plant and litter cover has come come in on most of the contour-trenched sites and very little storm runoff has been observed in recent years.

On some of the sites having very shallow and raw mineral soil plant cover is still too sparse to prevent runoff and erosion. The contour trenches on such sites, however, are continuing to trap runoff and eroded soil and thus prevent the concentration of overland flow into gully-ripping torrents. It has been found necessary to resort to contour trenching as an aid toward the rapid improvement of seriously deteriorated watershed conditions on several other flood-producing watersheds in Utah. The most recent extension of this method was made during the summer of 1950 on the Mt. Pleasant Watershed in central Utah.

Subalpine herbaceous range

The subalpine herbaceous summer range lies astride the tops of the highest mountains and plateaus of the Intermountain region. The high elevation subalpine range occupies but a small portion of the mountainous watershed lands. Normally, it produces a luxuriant cover of grasses and other herbs that is effective in controlling runoff and in keeping soil stable. Much of this range has been greatly depleted by overgrazing and because it is subject to high-intensity summer rains has become the source of destructive floods. The subalpine range on the Wasatch Plateau in central Utah, characterized by a heavy clay soil, is one of the most serious flood-source areas.

Storm runoff, erosion, and ground cover conditions have been measured on two 10-acre subalpine range watersheds on the Wasatch Plateau for the past 35 years. One of these watersheds had sparse, poor quality plant cover in 1915 as a result of past overgrazing. Runoff and erosion rates from summer storms were high. By 1929 with protection from grazing and some planting, there was substantial improvement in plant cover, and runoff and erosion rates had decreased materially. Since 1929 there has been further improvement in plant cover and a further reduction in runoff and erosion rates. Detailed analysis of records from this watershed show that the shift from larger to smaller amounts of runoff and erosion has been greater than could be expected as a result of differences in storm characteristics alone during the study period.

In spite of the improvement that has occurred on this experimental watershed, the ground cover conditions are still unsatisfactory for effective watershed protection. Too much surface runoff and erosion continue to occur during intense summer storms. Observations show that on only a small portion of this drainage basin is there enough vegetation to hold the soil firmly in place. Less than half of the area supports what may be termed fair cover. Slightly more than half of the watershed is characterized by poor cover, the amount of ground cover in many places being less than 30 percent. This depleted portion of the experimental watershed is made up of numerous small areas interspersed among areas having fair to good plant cover. These sparsely covered areas are still deteriorating and are the sources of by far the largest amounts of soil now being eroded from the watershed.

Infiltrometer tests, in which rainfall of about 1.5 inches per hour for a 20-minute period was applied to sites representing a wide range of cover conditions, confirm observations that the sparsely covered sites are producing the largest amounts of runoff and erosion on this watershed. From these tests a relationship between ground cover and amounts of storm runoff and erosion was developed as follows:

Average ground cover Percent	Storm runoff Percent	Soil eroded Lbs./A./storm
15	86.0	26,533
25	83.0	18,267
35	75.0	12,133
45	57.0	7,000
55	36.0	3,600
65	22.0	1,800
75	12.0	1,400
85	4.3	1,067
95	0.8	733

The tabular values show that, with a decrease in ground cover from about 95 percent to approximately 65 percent, storm runoff increased from less than 1 percent to about 22 percent and eroded soil increased from 733 to 1,800 pounds per acre. With a further decrease in ground cover to 55 percent, runoff increased to 36 percent and eroded soil jumped to 3,600 pounds per acre. Further decreases in ground water resulted in increasingly larger runoff and soil losses. A ground cover of about 65 percent, therefore, appears to be the minimum necessary to prevent excessively high rates of storm flow and soil erosion from originating on local subalpine range sites. This amount of ground cover compares closely with the amounts needed to prevent accelerated runoff and erosion from aspen-herbaceous summer range in northern Utah and spring-fall grassland range in Idaho.

Additional analyses of infiltrometer data have revealed that storm runoff and erosion from subalpine range is also related to the size of bare soil openings and volume-weight of the soil. The smaller the bare areas for any given ground cover, the more efficient was the ground cover in controlling storm flow and erosion. Here again, the effects of bare soil openings are similar to those found on the Boise ranges. Storm runoff and erosion were considerably higher on eroded heavy soil than on uneroded light soil containing more incorporated organic matter. This difference may be due, in part, to the lighter, more porous structure of uneroded soil surfaces which provided for more rapid infiltration.

Safe runoff and erosion losses from subalpine range apparently depend upon the presence of good ground cover and small bare soil openings but natural recovery of depleted range to safe ground cover conditions apparently is a slow process. Artificial revegetation and perhaps even supplemental mechanical control by contour trenching appear essential for accomplishing rapid recovery on the most depleted and eroded sites.

Summary

Practically all of the studies on these three important range problem areas have been directed toward determining the ground cover conditions that are required for controlling accelerated summer storm runoff and soil erosion, spot-by-spot. It is rather remarkable that all of these areas, having widely divergent plant cover and soil characteristics, require at least two-thirds of the ground to be covered by plant and litter material before localized control of runoff and erosion can be expected during torrential rains.

The size of bare soil openings and the uniformity with which they are dispersed has also been found to be an important site characteristic affecting the control of storm runoff and erosion. On the coarse-textured, granitic soil, grassland range in Idaho and the heavy, clay soil, subalpine range in central Utah, large bare soil openings decreased the effectiveness of plant cover, while small, uniformly spaced openings increased its effectiveness for controlling runoff and keeping soil stable. The influence of the size of bare soil openings is most effective with a ground cover of 65 percent or more. On sites where growing conditions preclude the attainment of a 65-percent plant and litter ground cover, management should strive for the smallest and most uniformly spaced bare openings possible.

On the granitic-grassland range it has been shown also that very heavy trampling disturbance results in substantial increases in storm runoff and erosion by reducing the amount of ground cover and increasing the size of bare soil openings. Determination of the safe limit of trampling and grazing disturbance will require further study.

It should be borne in mind that the plant cover and soil requirements developed by these spot-by-spot studies provide effective control of runoff and erosion only at the study sites (source areas). The extent to which the plant cover and soil conditions that provide this type of local control might be capable of controlling runoff at locations below source areas is not known and presents another research problem. Pending the development of watershed requirements for this more extensive type of control, the criteria thus far developed for the local control of storm runoff and erosion provide useful tentative watershed management goals.

PROGRAM FOR 1951

The bulk of the effort at all the research centers this year will be devoted to the completion of reports including manuscripts for publication, problem analyses, and the preparation and revision of study plans. The magnitude of these jobs will preclude all but a minimum of routine field work on going studies.

At the Boise Research Center, reports will be completed on a snow accumulation and melting study, a problem analysis, and a comprehensive progress report on the development of criteria for protection of spring-fall range lands. Study plans will also be prepared for investigations on the effects of livestock trampling disturbance and of ponderosa pine logging on erosion, and on factors affecting snow melt in ponderosa pine. Field work will be limited to continuation of a cooperative study with the range reseeding division on methods of stabilizing eroding granitic soil.

At the Wasatch Research Center, reports will be completed on evapotranspiration losses from the aspen and herbaceous cover types and on the behavior of the Parrish runoff plots. It is also planned to develop a problem analysis for the Wasatch province and to review and bring up-to-date all study plans. Field work will be limited to a continuation of climatic, stream flow, and Parrish plot records.

At the Great Basin Research Center, effort will be devoted to completion of the A-B watershed analyses and the development of a report thereon, and to the development of a problem analysis for the Great Basin province. Field work will be limited to continuation of records on the A and B, West Fork, and Alpine Cattle Pasture watersheds.

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STATION PERSONNEL, C.Y. 1950

ADMINISTRATION

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RANGE RESEARCH

Grazing Management

Lincoln Ellison	Range Conservationist (R)
Odell Julander	Range Conservationist (R)
Selar S. Hutchings	Range Conservationist (R)
James P. Blaisdell	Range Conservationist (R)
Justin G. Smith	Range Conservationist (R)
William J. McGinnies	Range Conservationist (R)
Walter F. Mueggler	Range Conservationist (R)
Walter R. Houston	Research Forester
Paul E. Hansen	Range Aid (Research)
Evan R. Johnson	Clerk-Steno.

Range Reseeding

George Stewart	Range Conservationist (R)
Gerard J. Klomp	Range Conservationist (R)
A. Perry Plummer	Range Conservationist (R)
Alvin T. Bleak	Range Conservationist (R)
John M. Fenley	Range Conservationist (R)
Neil C. Frischknecht	Range Conservationist (R)
Ralph C. Holmgren	Range Conservationist (R)

FOREST AND RANGE ECONOMICS

J. O. Lammi	Forest Economist (Resources)

FOREST AND RANGE INFLUENCES

George W. Craddock	Forester (Forest Influences)
A. Russell Croft	Forester (Forest Influences)
Paul E. Packer	Forester (Forest Influences)
Richard B. Marston	Forester (Forest Influences)
Howard K. Orr	Forester (Forest Influences)
Lawrence V. Monninger	Range Conservationist (R)
Harold F. Haupt	Range Conservationist (R)
Alden Blain	Range Aid (Research)

FLOOD CONTROL SURVEYS

Henry L. Lobenstein	Forester (Forest Influences)
John A. Adams, Jr.	Engineer (Civil)
Elon H. Bomberger	Forester (Forest Influences)
J. Marvin Rosa	Hydrologist
Albert R. Blanch	Forester (Forest Influences)
Olaf C. Olson	Soil Scientist
Harold H. Price	Forester (Forest Influences)
Vincent W. Twoomey	Forester (Forest Influences)
George W. Carlson	Forester (Forest Influences)
William E. Murray	Forester (Forest Influences)
Merle H. Tigerman	Forester (Forest Influences)
Byron F. Thurmond	Cartographic Engineer
Richard W. Payne	Engineering Draftsman

FOREST MANAGEMENT

James D. Curtis	Forester (Research Adm.)
Alvin K. Wilson	Forester (Silviculture)